LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS

CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

JOURNAL DU CONSEIL

VOL. XIII · NO. 1

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR

E. S. RUSSELL

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

AVRIL 1938

Notice.

The Journal of the Council appears *three times a year*, and three numbers form a volume. It includes, in addition to general articles, reviews, and bibliography, the special papers previously issued in the series of *Publications de Circonstance.*

The annual subscription price is 12 Kroner (+ Kr. 1.90 for mailing expenses) a volume, which includes, if desired, a reprint of the bibliographical matter, printed on one side of the paper. Single copies are sold at Kr. 4.50.

Orders for copies should be sent to **Messrs. Andr. Fred. Høst & Søn, Bredgade, Copenhagen.**

Correspondence, books and papers for review or bibliographical notice, and all contributions to the Journal, should be addressed to the **Assistant Editor, Journal du Conseil, Fisheries Laboratory, Lowestoft, England.**

BUREAU DU
CONSEIL INTERNATIONAL
POUR L'EXPLORATION DE LA MER
Charlottenlund Slot, Charlottenlund

Journal du Conseil International pour l'Exploration de la Mer.

Copy for publication in the Journal should be addressed to the Assistant Editor, Journal du Conseil, Fisheries Laboratory, Lowestoft, England. All contributions must be in the English, French, German, or Spanish language.

General and scientific articles should be accompanied by a summary, preferably in one of the four languages other than that in which the main part is written. General articles and reviews, asked for by the Editor, are paid for at the rate of Kr. 10 a page. The payment for a general article shall not exceed Kr. 200. No payment is made for other articles. Authors of articles will receive 50 copies of their paper gratis.

Reviews should not exceed 600 words in length (one page). Reviewers are asked to give bibliographical details of the papers reviewed, in the following order: — Author: Title of paper; Name of publication, volume, and number; Number of pages, text figures, plates, etc.; Publisher's name (in the case of a book); Place and year of publication.

Preparation of Copy for Press. Contributors should submit type-scripts and figures in a state fully prepared for press, according to the instructions which follow, in order that the costs of proof correction may be reduced to a minimum, and no expense be incurred by the Council in re-drawing any figures.

1. All contributions should be type-written, on one side of the paper only.

2. Diagrams should be prepared in waterproof Indian Ink (Encre de Chine) on Bristol Board or other perfectly smooth, white paper or card. No erasures should be made. Shading should be limited to the minimum necessary, and when used the shading lines should be kept open. Fine and dotted lines should be drawn boldly. Lettering should be inserted only in pencil: the block-maker will fill in the definitive lettering.

Diagrams should, if possible, be twice the diameter required, and when reduced should occupy a maximum space of 18 cm. in length and 11 cm. in width, including the space for the legend. The shape should be such as to fit easily into the page. The size to which drawings are to be reduced should be noted in pencil on the originals.

Charts and curves may be drawn to advantage on graph-paper ruled in pale blue lines, as these do not appear in photographic reproduction.

3. For satisfactory reproduction of photographs a good glossy bromide print is required, and all added matter, such as reference letters, arrows, numbers, etc. should be drawn either on tracing paper attached to the back of the print and folded over the front, or on the face of the photograph. In the latter case a duplicate print without the added matter should be supplied.

Legends for figures or photographs should be type-written on a separate slip of paper fastened to the appropriate figure.

Digitized by the Internet Archive
in 2025

https://archive.org/details/ices-journal-of-marine-science_1938-04_13_1

CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

JOURNAL DU CONSEIL

VOL. XIII · NO. 1

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR
E. S. RUSSELL

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

AVRIL 1938

IMPRIMERIE A/S L. IHRICH

Charles Green

1876—1938.

THE death on the 9th of February of Charles Green, for many years Chief Inspector of Fisheries in the Irish Free State will be very deeply regretted by all his many friends.

Charles Green was born in 1876 and was the only son of the Rev. William Spotswood Green, who

was distinguished as a geographer and as a pioneer of fishery research on the Irish coasts. He was educated at St. Edward's School, Oxford, and Trinity College, Dublin, where he obtained the highest awards in natural science. In 1898 he worked as assistant to E. W. L. Holt in a floating laboratory which had been established by the Royal Dublin Society in Connemara; in 1900 he accepted a post as Naturalist in the Fisheries Branch of the Department of Agriculture, which had been reconstituted with his father as Inspector and Holt as Scientific Adviser. When his father retired in 1914 Holt became Chief Inspector and in 1922 Charles Green succeeded him, first as Inspector and later, in 1926, as Chief Inspector.

Though possessed of a most critical mind, and with the highest appreciation of the value of scientific methods in fishery problems, Green's personal contributions to fisheries literature have been few. From an early date he recognized the need for an efficient fisheries administration in Ireland, and it is as a wise administrator through many years of strain and difficulty that he will long be remembered.

The foundation of the Irish Free State brought with it changes in policy and many problems of extreme difficulty, under which a lesser man would have lost heart; but he never wavered either in faith in his Department or, as a civil servant, in loyalty to the new constitution. His great intellectual attainments and his intimate acquaintance with every aspect of Irish fisheries commanded respect, and the changes were carried through, in a way that he alone could have done, without any sacrifice of essentials or departure from the principle that fishery administration must always be founded upon a well-built basis of scientific fact.

Charles Green had a passion for accuracy and for orderly method, and his knowledge was truly prodigious. In the midst of heavy administrative work he found time to keep abreast of every development in fishery science, and throughout his life he maintained his interests — begun at school and continued as a classical scholar of Trinity College — in literature and art. Those who saw him only in an official capacity knew but one side of his many abilities, and though they must have made acquaintance with the charm of manner and the sense of humour which he inherited from his father, they could scarcely have realized his wide culture and his critical appreciation of such subjects as music and poetry. He had a marked originality of mind: in works of art he found, and could explain to his listeners, beauties that they had not

before suspected, and there was scarcely a topic on which he could not present new and stimulating ideas. In pen and ink he was an accomplished artist, and a fine craftsman in both wood and metal, taking pride in mastery of detail and perfection of workmanship. His thorough practical knowledge was often of much value in his official work. He had much to say in planning the research ship which belongs to the Department, and for some thirty years this ship, first as the "Helga" and in recent times as the "Muirchu", has repaid his forethought by her efficiency both in routine fishery duties and in acquiring new knowledge by her long series of scientific observations. In nature, and in animal life in particular, he took unbounded delight. For many years, as a member of Council, he gave much time to the work of the Royal Zoological Society of Dublin, and shortly before his death he was elected a Vice-President of the Society.

In the years before the war C h a r l e s G r e e n took part with regularity in the International Council meetings at Copenhagen — at first as an expert on the staff of the British Delegation and later as a Delegate from the Irish Free State. In recent years, with impaired health, he was rarely able to attend, but he was present at the meeting in Copenhagen in 1925 and that in London in 1929. His loss will be deplored by the many who had the good fortune to know him, but nowhere will it be felt more acutely than in the Department which owed so much to his wise counsel in a critical period of its existence.

S. K.

Editorial Note.

We welcome the appearance, in November last, of the first number of the *Journal of Marine Research,* published by the Sears Foundation for Marine Research, Bingham Oceanographic Laboratory, Yale University, New Haven, Conn. This journal is to be devoted to "any aspect of scientific marine investigations or any subject with a direct or indirect bearing upon the problems of the sea". It is to appear three times a year, and the annual subscription price is $ 3.

Water Movements in the Straits of Dover.*)

By

Joh. van Veen,
Rijkswaterstaat, den Haag.

THE streams were measured during some months in 1934 and several weeks in 1935 and 1936 with the so-called "heavy Ott" current-meter (Fig. 1), a well-known precision instrument. When strong currents had to be measured at great depths (up to 70 metres), it was found to be necessary for the instrument to weigh 100 kilograms. For weaker currents 50 kilograms sufficed. Every half-hour the currents were measured from top to bottom at intervals of 2 metres, but when the depth was large, these were increased to 5 metres.

It is a well-known fact that in turbulent water current-meters often give results which are either too high or too low. In the laboratory of Iowa, U.S.A., the engineers Yarnell and Nagler[1]) found that some types of instrument showed errors up to 200 % when measurements took place in very turbulent streams. Much attention was therefore given to the checking of our "Ott" current-meter during all weather conditions. A handy way of doing this is by using as submerged floats, small bits of sea-weed floating by the ship's side. These were timed for a distance of 25 metres by stop-watch. Repetition of this simple test shows not only that the checking is fairly accurate, but also that the "Ott" can be relied upon during all weather conditions. In order to avoid the influence of the ship's side, the instrument was hung at 2½ metres distance (see Fig. 1).

The direction of the streams was observed simultaneously by means of a Jacobsen meter (Fig. 2). We prefer pyramids to any other body, because pyramids (or cones) remain absolutely stable in a stream. The apex of the pyramid must point in the direction from which the current comes.

*) For more extensive information see: "Onderzoekingen in de Hoofden", with English and French summaries and 147 figures, by Joh. van Veen, Algemeene Landsdrukkerij, den Haag, 1936.

[1]) Yarnell and Nagler: "Effect of turbulence on the registration of current-meters." Am. Soc. of Civ. Eng., paper 1778, 1931.

The ship "Oceaan" which was used for these measurements is about 400 tons, and of the following dimensions:— depth 3·50 m., breadth 7·60 m., length 38·30 m. She does not move to-and-fro in the streams when at anchor, and rides very steadily in bad weather so that measurements can go on even during heavy gales. The custom is to continue measurements until the anchor starts to drag or until the specially heavy anchor-chain breaks.

The work of 1934 and 1935 enabled about 300 vertical diagrams of currents in the Straits of Dover to be prepared. They refer to 31 different spots with depths varying from 30 to 70 metres. In 1936, 392 similar diagrams were drawn for one point only, near Dover.

Fig. 1. The "heavy Ott" current-meter. It gives signals on board ship by means of electricity.

Stream-Diagrams for Verticals.

According to both old (1875 and later) and recent measurements of the Rijkswaterstaat, the diagrams for the currents from top to bottom show the following characteristics. The strongest currents occur at the surface, and velocity falls off with depth in such a manner that the diagrams resemble parabolas with vertical axes, whose vertices touch the bottom in the zero of the figure.

It should be added that most investigators reached other conclusions[2]); some found rectilinear or logarithmic forms, others elliptical or even parabolic ones with horizontal axes, etc. The German writers on this subject, Forchheimer[2]) (1931) and van Rinsum[3])

[2]) Ph. Forchheimer. Hydraulik, pp. 172—180, Leipzig, 1930.
[3]) Anton van Rinsum. Die Abflüsse in offenen natürl. Wasserläufen. Berlin 1935.

(1935), maintain that parabolic forms with vertical axes do not satisfactorily represent the stream-diagrams for a vertical. The German schools teach that the highest velocity occurs at some distance below the surface.

Apparently there is still much difference of opinion, though the problem is not very complicated. Nature itself may in some measure be the cause of these different opinions, because streams need not always yield the same diagram, and a contributory cause may lie in incorrect measurements or in unchecked instruments. Moreover, recent data are rare, so that van Rinsum (1935), for example, uses those of Jasmund (1893).

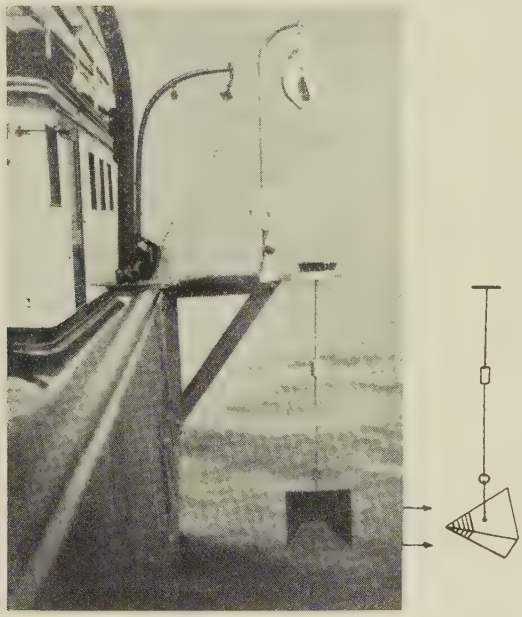


Fig. 2. The measuring of the current-direction by means of Jacobsen's device. A pyramid does not shake in any current.

The modern precision instruments for measuring water currents such as those of Ott or Rauschelbach are reliable, and it seems logical to expect that when those or any other good modern instruments are used, different opinions would unite in principles though some minor differences would remain. For instance, views might differ as to whether the fastest currents occur at the surface or at a small distance below it, because some instruments over-register and others under-register near the surface on account of wave-turbulence. Near steep shores and in laboratory channels the quickest currents do seem to lie below the surface, but the practical significance of this is not great.

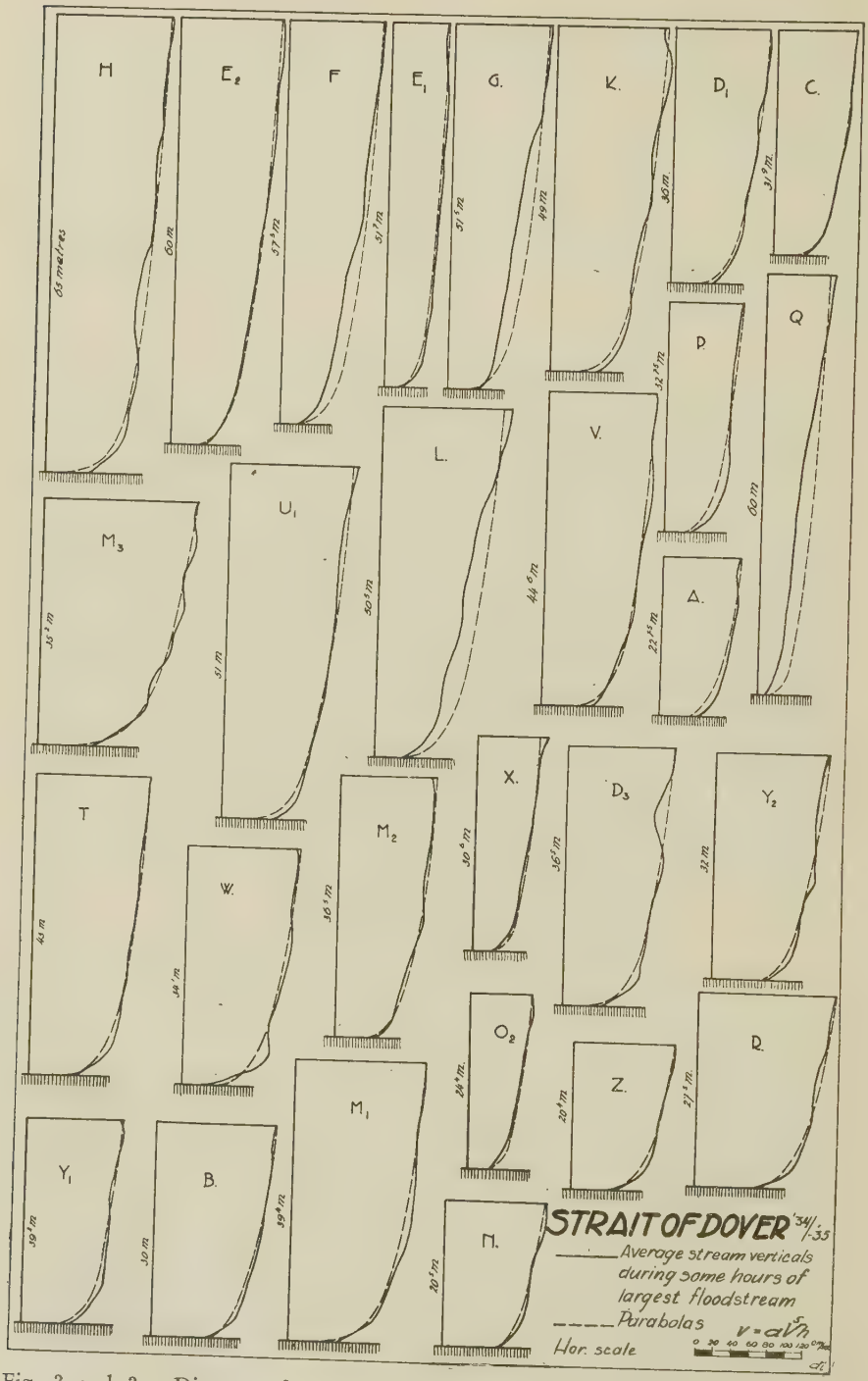
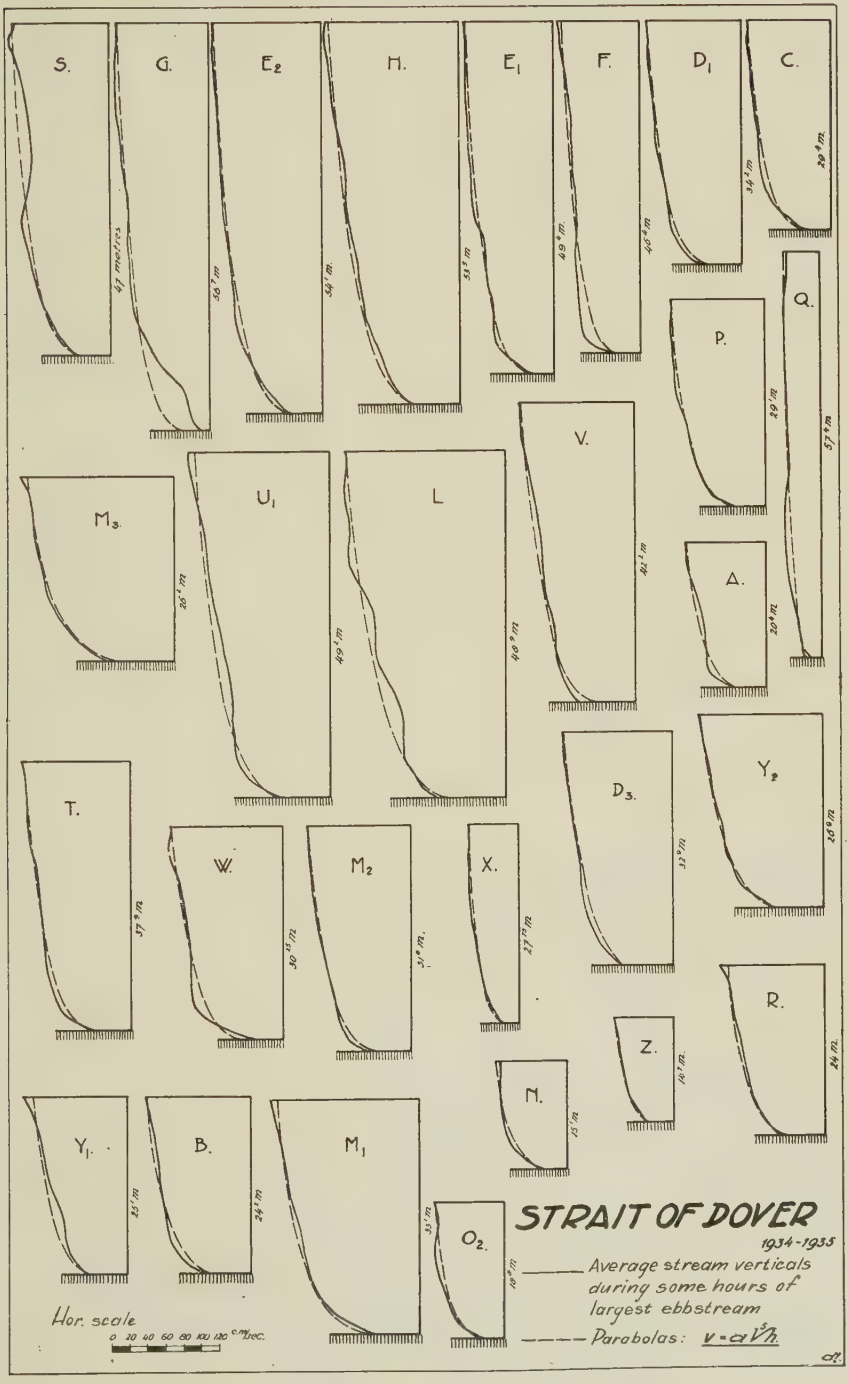


Fig. 3 and 3a. Diagrams for velocities from top to bottom in different places (refer to Fig. 16) of the Straits of Dover during flood and ebb.

Fig. 4. Diagrams for velocities from top to bottom at point D, 5 miles off Dover.


S.
G.
E2
H.
E1
F.
D1
C.
Q.
P.
V.
M3.
U1
L
A.
T.
W.
M2
X.
D3.
Y2
R.
Z.
N.
Y1.
B.
M1
O2.
STRAIT OF DOVER
1934-1935
Average stream verticals during some hours of largest ebbstream
Parabolas: v = a√h
Hor. scale
0 20 40 60 80 100 120 c.m/sec.

The thing that is not to be overlooked in practice is the simplicity of the formulae to be used. Formulae such as those of Hessle, Harden, Lavalle, Christen and others, in which many different factors are impressively included, may give good approximate results, but they cannot well be used for practical purposes.

Although the German writers on this subject discourage the use of parabolas with vertical axes, the present writer has tried whether the simplest parabola imaginable, namely

$$V = a \sqrt[q]{h} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

would fit the very extensive measurement data collected by the Rijkswaterstaat during the years 1931—1935 closely enough to be of practical value.

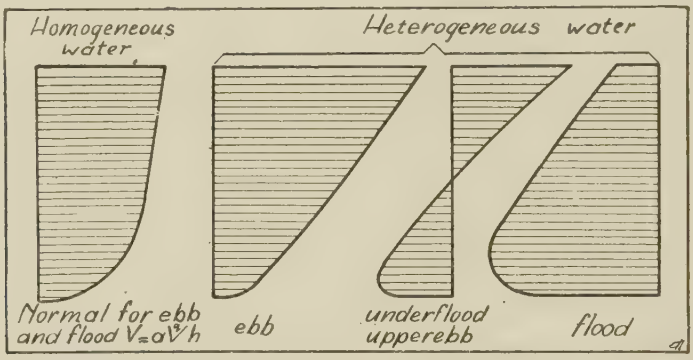


Fig. 5. Diagrams for velocities in heterogeneous water; salt below, fresh above.

In this formula V is the velocity at a height of h metres, and a the velocity at 1 metre above the bottom, while q is a figure which proved to be between 5 and 10.

Figures 3 and 4 give a number of specimens of stream-diagrams for verticals in the Straits of Dover, and show also the approximating parabolas.

The correspondence seems not only to be good enough for practical purposes, but the fact that sometimes the parabola is on one side of the measurement-graph and sometimes on the other side of it suggests that Formula 1, though simple, is more or less theoretically right too. The currents increase with distance from the bottom according to some regular law — at least when the density of the water is the same from top to bottom. When it is not, different types of diagram result, of which Fig. 5 gives some idea.

Generally we find that the differences in specific weight do not influence the form of the diagrams, when these differences remain under one per mille. The three distorted diagrams pictured at the right side of Figure 5 occur when differences in specific weight of about 5 to 20 per mille are apparent.

We never could find any distortion of the diagrams as resulting from wind. Therefore we cannot accept the theory taught in German shools that the friction between air and water causes lower velocity at the surface than at some deeper layer.

It should be remarked that the curves pictured in Figures 3 and 4 are the averages of about 6 individual ones, taken in one point of the stream during 3 successive hours of the main ebb and main flood. The individual diagrams of the currents from top to bottom show more irregular forms, because of pulsations (turbulence), which increase or decrease the mean velocity by about 10 %. The rather regular diagrams shown in Figures 3 and 4 could also have been obtained by taking measurements for at least 3 or 4 minutes at several points in the vertical, but in tidal streams this takes too much time, especially when the depth is considerable.

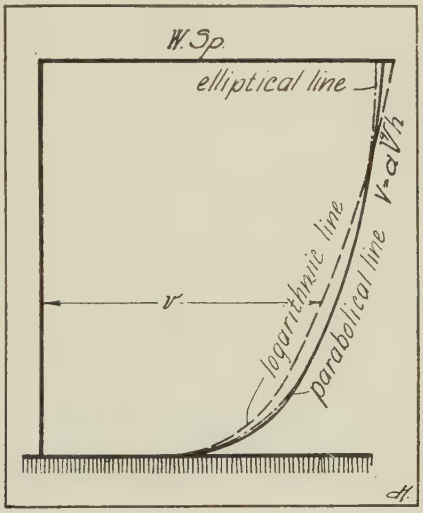


Fig. 6. Comparison of Jasmund's, van Rinsum's and van Veen's formulae.

In Figure 6, the formula of Jasmund,

$$V = A + B \,.\, \log(h + c) \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

and that of van Rinsum,

$$V = K_s \sqrt{Hi} + \mu \sqrt{(2Hh - h^2)\, i} \quad \ldots\ldots\ldots\ldots \quad (3)$$

are given graphically. Our Formula 1 is also shown, and it is seen that the three curves diverge little and that the simplest formula may be considered as possessing about the same exactness as those that are more complicated. Moreover, according to our experience, Jasmund's logarithmic line slopes too much near the surface, whereas van Rinsum's is too vertical there.

By means of the formula $V = a\sqrt[q]{h}$, we can determine the bottom, surface, and mean currents quite easily as soon as q and one single point of the vertical diagram are known. In this way the currents of the whole vertical can be learned from the data obtained with self-registering current-meters, working at one point only.

The advantage of the parabolic formula is its extremely simple integration. The mean velocity V_m is the $\frac{q}{q+1}$th part of the surface velocity V_s, and the area of the parabola is the $\frac{q}{q+1}$th part of the enveloping square. This is learned immediately by the integration:—

$$F = \int_0^H v\,dh = a\int_0^H h^{\frac{1}{q}}\,dh = \frac{q}{q+1} H v_{max}$$

The proportion

$$\gamma = \frac{q}{q+1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

is here called the "bloc-coefficient" of the parabola, and is expressed in the following formulae:—

$$\gamma = \frac{v_m}{v_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$V_m = \gamma\, a.H^{\frac{1}{q}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$V_s = a.H^{\frac{1}{q}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

when H is the total depth.

When comparing the γ's for the vertical diagrams in a river, or in a sea, one comes to the conclusion that γ does not change much in a particular area, provided the flow is regular and the water homogeneous up to one per mille.

In 1875—1879 Rijkswaterstaat engineers constructed 532 diagrams relating to the Rhine-Maas branches, and from them $\gamma = 0{\cdot}875$ can be deduced, which gives for these rivers:—

$$V = a\sqrt[7]{h}$$

This coefficient $\gamma = 0{\cdot}875$ is the same as found by Ehrenberger (1924) in the Donau canal, by comparing V_m and V_s.

For sea-inlets in the North Sea along the Dutch coast, and for the Straits of Dover too, we obtain a parabola in the equation for which $q = 5{\cdot}3$. In these places with more or less homogeneous water, the "Oceaan" obtained data sufficient for about 1,000 vertical-diagrams. The γ's of those relating to the Straits of Dover (Dutch: "Hoofden") are given in the following table. Reference to Figure 16 will show to what positions the letters in the second column refer.

Date	Observing Point	Flood Stream: Mean Depth in Metres	Flood Stream: "Bloc-Coefficient" γ	Flood Stream: Deviations from General Mean	Ebb Stream: Mean Depth in Metres	Ebb Stream: "Bloc-Coefficient" γ	Ebb Stream: Deviations from General Mean
14—6 1934	K	49	0·83	0			
15—6 1934	N	20·4	0·85	+0·02	15·1	0·87	+0·04
18—6 1934	O_1	—	—	—	11·1	0·89	+0·06
21—6 1934	G	51·5	0·73*	—0·10	56·7	0·79*	—0·04
25—6 1934	D_1	36	0·84	+0·01	34·2	0·84	+0·01
26—6 1934	E_2	60	0·84	+0·01	54·1	0·84	+0·01
27—6 1934	B	30	0·85	+0·02	24·2	0·85	+0·02
28—6 1934	H	65	0·82	—0·01	53·5	0·82	—0·01
3—7 1934	O_2	24·4	0·80	—0·03	18·8	0·84	+0·01
20—7 1934	M_2	36·5	0·84	+0·01	31·8	0·85	+0·02
23—7 1934	E_1	51·7	0·86	+0·03	49·4	0·84	+0·01
24—7 1934	F	57·3	0·76*	—0·07	46·4	0·83	0
25—7 1934	Z	20·5	0·84	+0·01	14·7	0·82	—0·01
26—7 1934	—	—	—	—	—	—	—
28—7 1934	D_2	—	—	—	32·4	0·83	0
31—7 1934	M_1	39·4	0·85	+0·02	33·1	0·82	—0·01
1—8 1934	I	71·5	0·86	+0·03	59·4	0·81	—0·02
7—8 1934	C	31·9	0·84	+0·01	29·4	0·82	—0·01
9—8 1934	D_3	36·5	0·83	0	32·9	0·86	+0·03
10—8 1934	Y_2	32·0	0·86	+0·03	26·9	0·83	0
4—6 1935	V	44·6	0·86	+0·03	42·2	0·82	—0·01
19—7 1935	M_3	35·2	0·83	0	26·2	0·84	+0·01
22—7 1935	L	50·5	0·73*	—0·10	48·9	0·81*	—0·02
21—8 1935	P	32·7⁵	0·85	+0·02	29·1	0·84	+0·01
22—8 1935	A	22·7⁵	0·85	+0·02	20·4	0·83	0
23—8 1935	X	30·6	0·79	—0·04	27·7⁵	0·83	0
24—8 1935	Q	60·0	0·70*	—0·13	57·4	0·89*	+0·06
26—8 1935	Y_1	29·2	0·85	+0·02	25·1	0·80	—0·03
28—8 1935	R	27·5	0·84	+0·01	24·0	0·82	—0·01
29—8 1935	U_1	51·0	0·83	0	49·2	0·81	—0·02
30—8 1935	W	34·1	0·85	+0·02	30·2⁵	0·85	+0·02
2—9 1935	S	—	—	—	47·0	0·82	—0·01
3—9 1935	T	43·0	0·84	+0·01	37·9	0·83	0
Mean Values of γ:		Flood 0·824			Ebb 0·834		

The mean "bloc-coefficient" obtained from these data is 0·830, and investigation of the deviations from that mean yields a "root-mean-square" value (σ) of 0·043. The appropriate formula is

$$V = a \sqrt[4.9]{h}$$

The standard deviation 0·043 is rather high when compared with other cases. For this good reasons exist, because the abnormal γ's always occurred at places where the bottom was very rocky and irregular (measuring points G, F, L, and Q: see Fig. 3). When these points[4]) are omitted, a much smaller σ value is obtained, namely, 0·006.

[4]) Asterisked in the table.

Then γ becomes 0·838 and the parabola for the Straits of Dover becomes about the same as found for the sea-currents in all other places in the neighbourhood of the Dutch coast, namely,

$$V = a \sqrt[5\cdot2]{h}$$

In 1936, a series of 392 diagrams was prepared for point D, 5 miles off Dover. The bottom there was rather flat and about 35 metres below the mean surface level. The diagrams, which were averaged by taking groups of 5 or 6 for every ebb and for every flood, are shown in Fig. 4. The results are

$$\gamma = 0\cdot845, \qquad \sigma = 0\cdot0106, \qquad V = a \sqrt[5\cdot4]{h}$$

The relevant data are set out in the following table, in which σ_f and σ_e denote deviations from the mean for flood and ebb respectively, and wind strength is expressed in metres per second as observed onboard the surveying ship:

Day of June 1936	Flood γ_f	Ebb γ_e	σ_f	$\sigma_f^2 \times 10^{-6}$	σ_e	$\sigma_e^2 \times 10^{-6}$	Wind Direction and Strength
13	0·820	0·838	—0·025	625	—0·007	49	E. — 4
13	0·838	0·849	—0·007	49	+0·004	16	SW. — 11 to 13
14	0·860	0·832	+0·015	225	—0·013	169	SW. — 7 to 8
14	0·844	0·860	—0·001	1	+0·015	225	NW. — 6
15	0·850	0·847	+0·005	25	—0·002	4	SW. — 14
15		0·810			—0·035	1225	SW. — 14
16	0·850	0·831	+0·005	25	—0·014	196	SW. — 7
16	0·842	0·861	—0·003	9	+0·016	256	SW. — 8
17	0·840	0·830	—0·005	25	—0·015	225	SW. — 4
17/18	0·840	0·842	—0·005	25	—0·003	9	SE. — 6
18	0·850	0·845	+0·005	25	0	0	NW. — 4
18/19	0·841	0·847	—0·004	16	+0·002	4	SE. — 6
19	0·848	0·856	+0·003	9	+0·011	121	NE. — 4
19/20	0·842	0·838	—0·003	9	—0·007	49	E. — 5
20	0·849	0·844	+0·004	16	—0·001	1	NE. — 4
21	0·842	0·846	—0·003	9	+0·001	1	SE. — 3
21	0·851	0·851	+0·006	36	+0·006	36	SW. — 11
22	0·846	0·864	+0·001	1	+0·019	361	SW. — 5
22	0·830	0·848	—0·015	225	+0·003	9	SW. — 3
23	0·848	0·855	+0·003	9	+0·010	100	E. — 2
23	0·840	0·829	—0·005	25	—0·016	256	E. — 2
24	0·847	0·850	+0·002	4	+0·005	25	N. — 3
24	0·852	0·830	+0·007	49	—0·015	225	NE. — 4
25	0·854	0·850	+0·009	81	+0·005	25	NE. — 6
25	0·841	0·843	—0·004	16	—0·002	4	NE. — 5
26	0·855	0·872	+0·010	100	+0·027	729	N. — 3
26	0·839	0·845	—0·006	36	0	0	NE. — 2
27	0·841	0·852	—0·004	16	+0·007	49	Calm
27	0·830	0·849	—0·015	225	+0·004	16	Calm
28	0·841	0·868	—0·004	16	+0·023	529	SE. — 2
28	0·838	0·850	—0·007	49	+0·005	25	NE. — 4
29	0·848	0·850	+0·003	9	+0·005	25	N. — 4
29	0·830		—0·015	225			SW. — 2
Means and Sums	0.843	0·846		2215		4964	
	0·845						

$$\sigma = \sqrt{\frac{0{\cdot}002215 + 0{\cdot}004964}{64}} = 0{\cdot}0106.$$

We generally take $q = 5{\cdot}3$ for homogeneous Dutch tidal waters. It follows that the mean velocity V_m according to Formula 6 occurs at a height of

$$0{\cdot}4\ H$$

above the bottom, where H is the total depth.

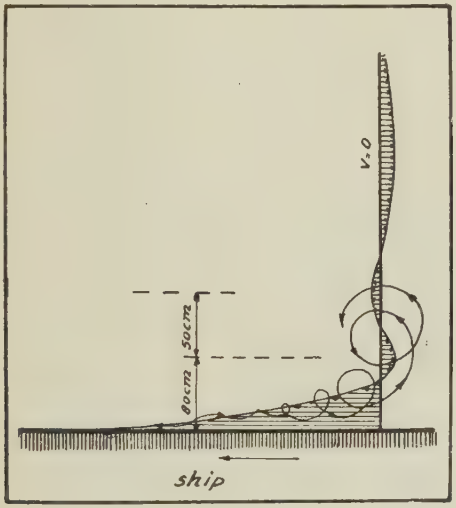


Fig. 7. Velocity distribution near to the side of a moving ship.

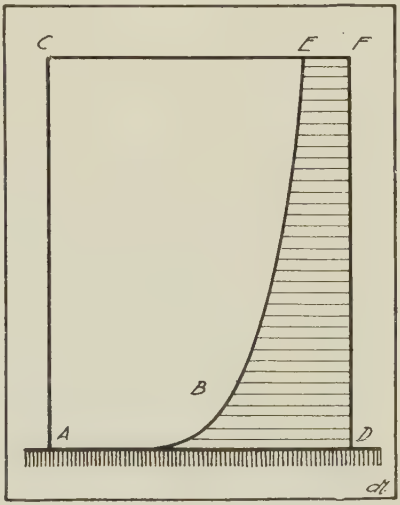


Fig. 8. Diagram showing how friction would limit the transmission of velocity upwards from a sea-floor supposed to be in motion.

It should be clear that high rocks or huge sand-waves on the bottom may disturb the regular distribution of the currents to some extent, while heterogeneous water may disturb it greatly.

Many writers suppose that there exists a so-called bottom-velocity V_b, and they draw the velocity diagram in such a way that it touches the bottom at a distance V_b from the zero of the figure. They therefore find a formula composed of two terms $V_b + V_h$, in which V_b is constant and V_h varies with the height above the bottom.

This is not in accordance with natural phenomena. Even if the bottom were quite flat and smooth the lowest layer of all would not move. The layer immediately above the lowest layer would have a small velocity, exceeded by that of the layer above it, and so on. There can be no sudden changes and the point of contact of the diagram with the bottom has to coincide with the zero of the figure. An

analogous state of affairs can be noticed when looking over the side of a moving ship (Fig. 7). The internal friction of the water layers, and much more so the turbulence, cause the 2nd, 3rd, 4th, ... layers to be dragged in the direction of the moving ship. The greater the distance from the ship, the smaller is the force which causes the water to be dragged along with it.

In analogy with a moving ship we can imagine the sea-bed (or river-bed) moving with a constant velocity AD (Fig. 8) and the water at rest. The bottom would drag the water with it, the lowest layers more so than the higher ones.

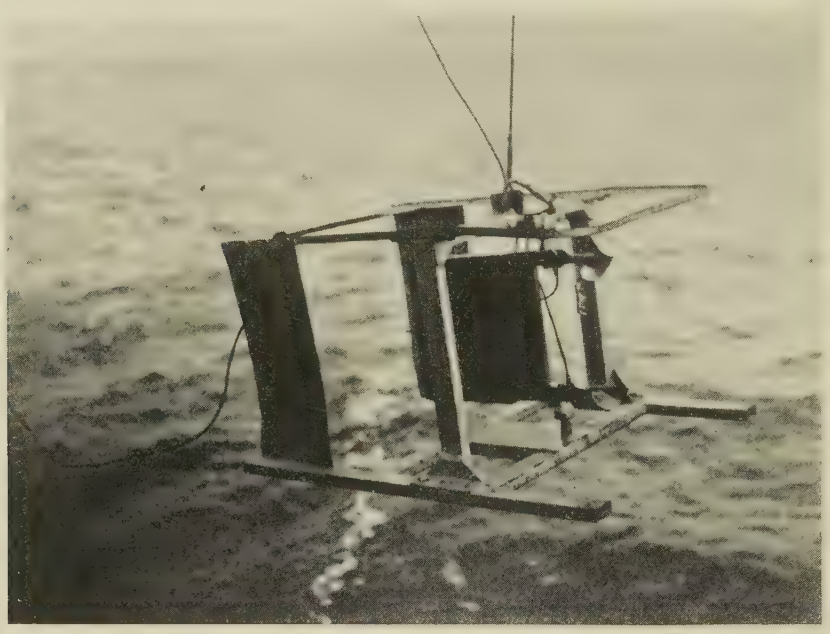


Fig. 9. Ott current-meter for measuring bottom-currents continuously.

The width of the shaded area at any depth would denote what proportion of the velocity was transmitted upwards to that depth. If we knew the imaginary velocity AD, we could calculate the shaded area, and so obtain a figure for the internal and external friction in the stream.

Periodic Changes in the Streams through the Straits of Dover.

From the 13th to the 31st June 1936, the "Oceaan" lay at a point 5 miles off Dover and measured the streams there from top to bottom during 16 successive days and nights. The position is referred to as point D, and its precise location was 51°4′30″N. Lat., 1°25′30″E. Long. Stream-verticals were obtained at every half-hour, and the streams at

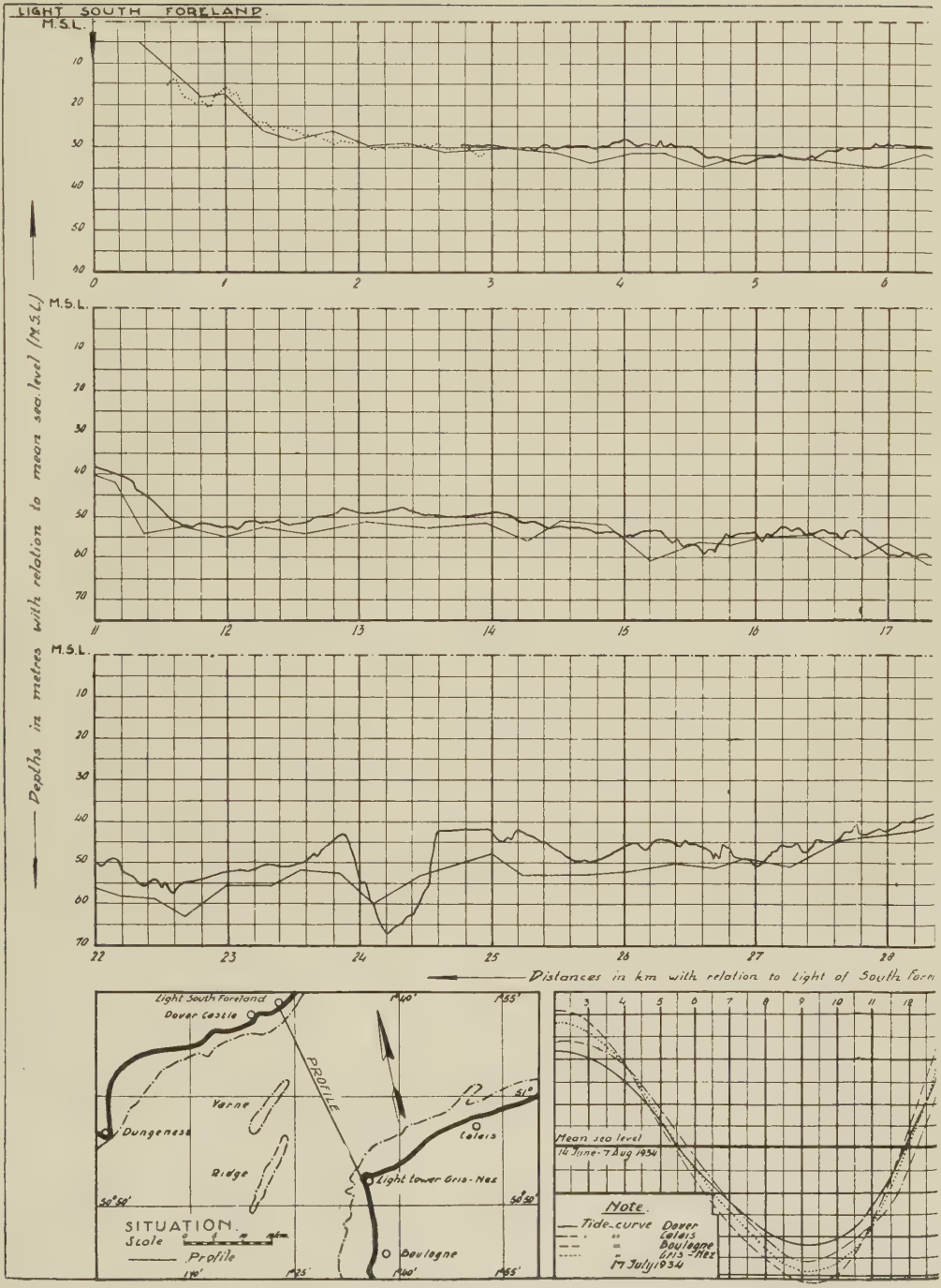


Fig. 10. Graph showing results of measurements for 16 days at point D off Dover.

10 m. depth and at 0·15 m. and 0·50 m. above the bottom were registered continuously. At the lowest levels the instrument shown in Fig. 9 was used.

The vertical tide was registered by the tide-gauge at Dover, and the mean amplitude during the period of observation was found to be 15·13 feet, which is about normal (15·2 feet).

The mean velocity at 10 m. below the surface was 31·2 kilometres per tide, or 69·6 cm. per second. It was 16·3 kilometres per mean total ebb and 14·9 kilometres per mean total flood. The mean ebb-current was 1·35 kilometres per tide larger than the mean flood-current.

The mean velocity from top to bottom (V_m) was lower, of course. It was 28 kilometres per tide or 62·7 cm. per second, composed of 14·7 kilometres per ebb tide and 13·3 kilometres per flood tide. A graph of the horizontal tide at 10 m. depth at D and of the vertical tide at Dover is given in Fig. 10. Spring tides occurred around 21st June 1936. There is a marked difference between day and night streams, but not during the period 17—19 June (just before New Moon). The exact data are given below.

At the beginning of the period strong south-westerly winds prevailed, and a marked flood-excess was measured during 14—15 June (see the lowest graph of Fig. 10). Later the winds were variable, and, in general, an ebb-excess occurred. The regular *daily periodical alternation of flood-excess and ebb-excess* is typical for the Straits of Dover. It is hardly perceptible in the Dutch tidal waters.

The atmospheric pressure did not change much during the fortnight, as is also shown in Fig. 10.

The analysis of the stream-curve (horizontal tide) for the period 14—28 June 1936 at D and of the tidal curve at Dover (vertical tide) for the same period gave the following results:—

Horizontal Tide at Dover (10 m. below surface)				Vertical Tide at Dover	
Tide	Period	Kappa	Amplitude	Kappa	Amplitude
M_2	12·4 h.	10°	109 cm./sec.	337°	237 cm.
S_2	12·0 h.	63°	26 cm./sec.	33°	55 cm.
M_4	6·2 h.	292°	9·6 cm./sec.	235°	30 cm.
O	25·8 h.	32°	12·7 cm./sec.	184°	9·1 cm.
K_2	11·97 h.	63°	6·8 cm./sec.	33°	14 cm.
K_1	23·93 h.	178°	10·1 cm./sec.	13°	6·4 cm.
P	24·07 h.	178°	5 cm./sec.	13°	3·2 cm.

It should be noted that as regards the daily period, the vertical tides are "out of step" with the horizontal tides (see Figure 10). The amplitude of 109 cm./sec. means the highest ebb and flood velocity of the horizontal M_2 tide, etc.

The stream-rose at normal tide for D is given in Fig. 11. The fastest mean ebb-stream at D at the depth of 10 m. was found to be 110 cm. per second, and the fastest mean flood-stream at the same depth, 107 cm. per second (mean figures of all measured tides).

Observations at Point D (51°04′30″ N., 1°25′30″ E.), 5 miles off Dover, during the cm./sec. on the left, and directions (degrees from North through East)

Time \ Hour after Dover H.W.	0 H.W. Dover		1		2		3		4		5	
13. 6. 1936												
5h15′.	—	—	108	55°	90	52°	59	63°	15	93°	37	207°
	49	43°	89	50°	86	50°	69	60°	35	68°	3	148°
	97	53°	111	49°	84	53°	55	65°	16	70°	30	205°
	76	50°	92	53°	94	60°	77	56°	47	62°	9	80°
	108	50°	113	50°	101	51°	62	67°	21	70°	19	145°
	83	47°	112	54°	108	54°	84	65°	34	64°	6	113°
	108	50°	117	50°	102	52°	67	77°	27	55°	16	205°
	85	50°	111	50°	104	51°	70	50°	34	60°	14	181°
	106	50°	121	52°	106	52°	72	55°	30	61°	15	230°
	96	46°	114	50°	108	58°	81	57°	30	48°	26	204°
	97	45°	120	50°	121	55°	68	57°	28	187°	25	223°
	101	50°	126	55°	112	51°	70	50°	21	80°	34	225°
	92	54°	125	50°	118	50°	81	60°	32	84°	9	171°
	115	52°	139	51°	119	55°	79	55°	30	65°	28	210°
	94	50°	124	52°	120	55°	83	60°	37	75°	11	180°
	124	45°	145	50°	122	50°	75	57°	25	68°	33	217°
	86	48°	124	54°	118	53°	80	54°	36	60°	9	125°
	120	45°	131	50°	115	51°	71	52°	30	60°	25	210°
	79	50°	119	42°	110	53°	81	50°	40	65°	10	168°
	134	53°	142	59°	116	60°	68	50°	20	80°	35	208°
	60	36°	109	45°	105	50°	77	55°	30	60°	12	300°
	120	50°	128	50°	106	50°	60	47°	12	84°	28	219°
	54	60°	94	57°	90	50°	68	60°	27	56°	8	175°
	104	46°	120	50°	96	55°	55	51°	8	65°	25	207°
	26	45°	78	46°	81	50°	54	50°	21	15°	12	195°
	94	46°	100	50°	88	59°	47	50°	4	69°	32	220°
	38	44°	68	65°	69	55°	51	55°	22	62°	—	—
	75	54°	82	53°	66	50°	32	50°	0	—	35	218°
	32	46°	61	50°	65	55°	39	55°	21	62°	10	183°
	66	45°	72	52°	59	55°	29	60°	0	—	32	215°
	29	65°	59	48°	60	45°	42	56°	18	70°	9	170°
	68	50°	62	58°	48	53°	32	53°	7	134°	41	194°
Means	83	49°	106	52°	97	53°	63	57°	23	68°	18	207°

Reduction Graphs.

There exists a general empirical relation between the horizontal tide and the vertical tide. At spring tides the amplitude at Dover is much higher than at neap tides and correspondingly the streams at springs are much stronger than those at neaps.

When we put this relation down graphically, we obtain, as in Fig. 12, a "cloud" of points through which we can draw a straight line. The angle α of this line with the horizontal axis can be calculated according to the theory of correlation by using the formulae

period 13th to 29th June 1936. Stream speeds at 10 metres depth are given in on the right. Data are presented for full lunar hours after Dover H.W.

6		7		8		9		10		11		Hour after Dover H.W. / Time	
88	215°	108	225°	129	225°	116	225°	66	215°	3	270°		
30	222°	75	220°	84	220°	57	223°	7	290°	57	45°		
80	224°	110	225°	123	220°	110	225°	57	239°	14	322°		
21	250°	46	175°	56	242°	41	225°	18	68°	81	51°		
83	243°	116	225°	127	221°	108	240°	55	245°	25	36°		
54	215°	87	221°	99	227°	83	230°	17	240°	57	41°		
83	240°	101	225°	120	229°	100	230°	45	240°	28	37°		
71	230°	100	228°	113	230°	94	230°	33	235°	51	45°		
80	215°	111	229°	120	225°	109	227°	51	235°	35	50°		
83	220°	111	231°	125	226°	119	232°	62	232°	32	110°		
82	231°	114	225°	128	225°	119	227°	59	230°	33	60°		
88	221°	120	230°	140	230°	139	230°	76	230°	10	73°		
72	225°	109	230°	125	230°	116	230°	48	242°	49	45°		
90	230°	122	232°	147	230°	142	225°	85	235°	8	350°		
75	216°	108	228°	125	228°	115	230°	39	235°	65	48°		
88	230°	125	228°	149	226°	148	230°	82	230°	0	—		
54	210°	110	216°	116	228°	99	230°	31	238°	74	42°		
87	227°	122	228°	141	230°	139	230°	82	235°	—	—		
60	245°	95	225°	106	225°	77	232°	16	257°	71	43°		
96	216°	129	228°	135	230°	138	230°	83	238°	—	—		
57	218°	84	225°	99	225°	81	225°	23	264°	60	41°		
80	211°	112	230°	138	225°	132	230°	86	225°	—	—		
48	195°	81	219°	93	225°	74	227°	18	236°	57	48°		
78	221°	109	220°	129	225°	133	225°	86	225°	28	228°		
52	215°	82	225°	87	220°	67	220°	—	—	49	72°		
75	218°	99	220°	114	225°	110	225°	69	225°	15	239°		
37	200°	64	225°	69	225°	48	227°	14	226°	32	45°		
75	225°	94	220°	99	225°	90	225°	47	228°	—	—		
43	216°	62	224°	67	224°	47	231°	—	—	29	65°		
64	215°	79	218°	82	223°	66	225°	44	221°	0	—		
43	212°	53	225°	52	215°	43	232°	—	—	45	65°		
71	224°	81	216°	77	225°	62	230°	32	230°	8	30°	29. 6. 1936 $19^h28'$.	
67	222°	97	224°	110	226°	97	229°	48	232°	33	49°	Means	

$$\sigma_1 = \sqrt{\frac{\Sigma x_1^2}{n}}, \qquad \sigma_2 = \sqrt{\frac{\Sigma x_2^2}{n}}$$

$$r = \frac{\Sigma x_1 x_2}{n \cdot \sigma_1 \sigma_2}, \qquad \alpha = -r\,\frac{\sigma_1}{\sigma_2}$$

We then obtain the following reduction table, which is the same for both ebb and flood:—

Amplitude in feet at Dover	Amplitude in % of Average	Reduction-Factor for the Streams	Amplitude in feet at Dover	Amplitude in % of Average	Reduction-Factor for the Streams
7·6	50	35	Mean 15·2	100	100
8·4	55	42	16·0	105	106
9·1	60	48	16·7	110	113
9·9	65	54	17·5	115	120
10·6	70	61	18·2	120	126
11·4	75	68	19·0	125	132
12·2	80	74	19·8	130	139
12·9	85	80	20·5	135	146
13·7	90	87	21·3	140	152
14·4	95	94	22·0	145	158
Mean 15·2	100	100	22·8	150	165

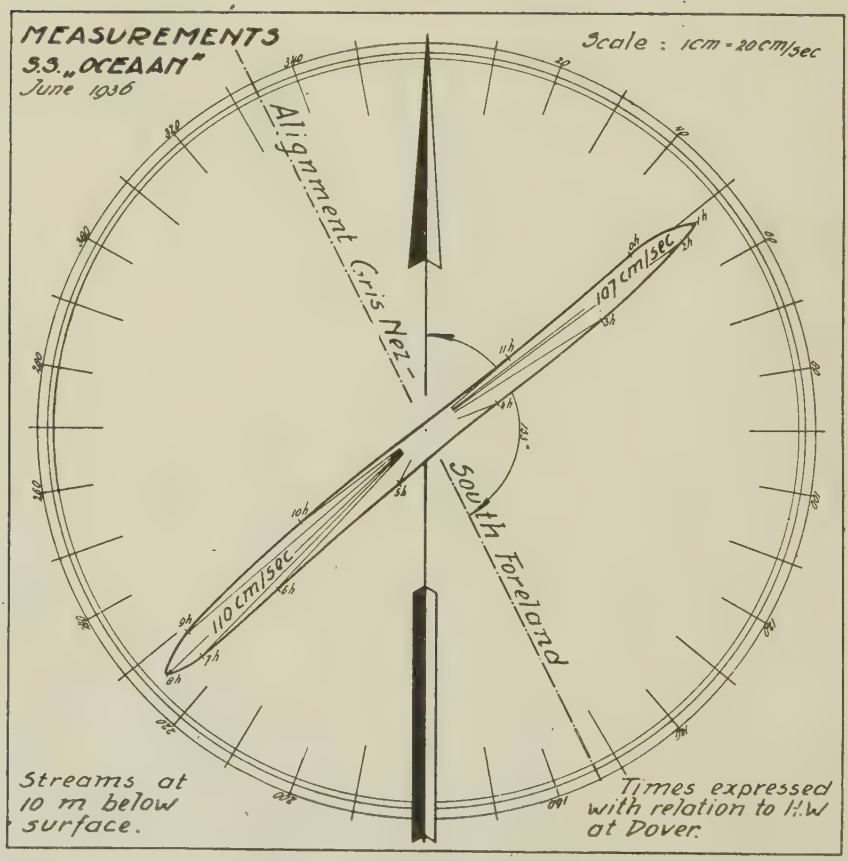


Fig. 11. Stream-rose for point D embracing the results of observations throughout 32 successive tides.

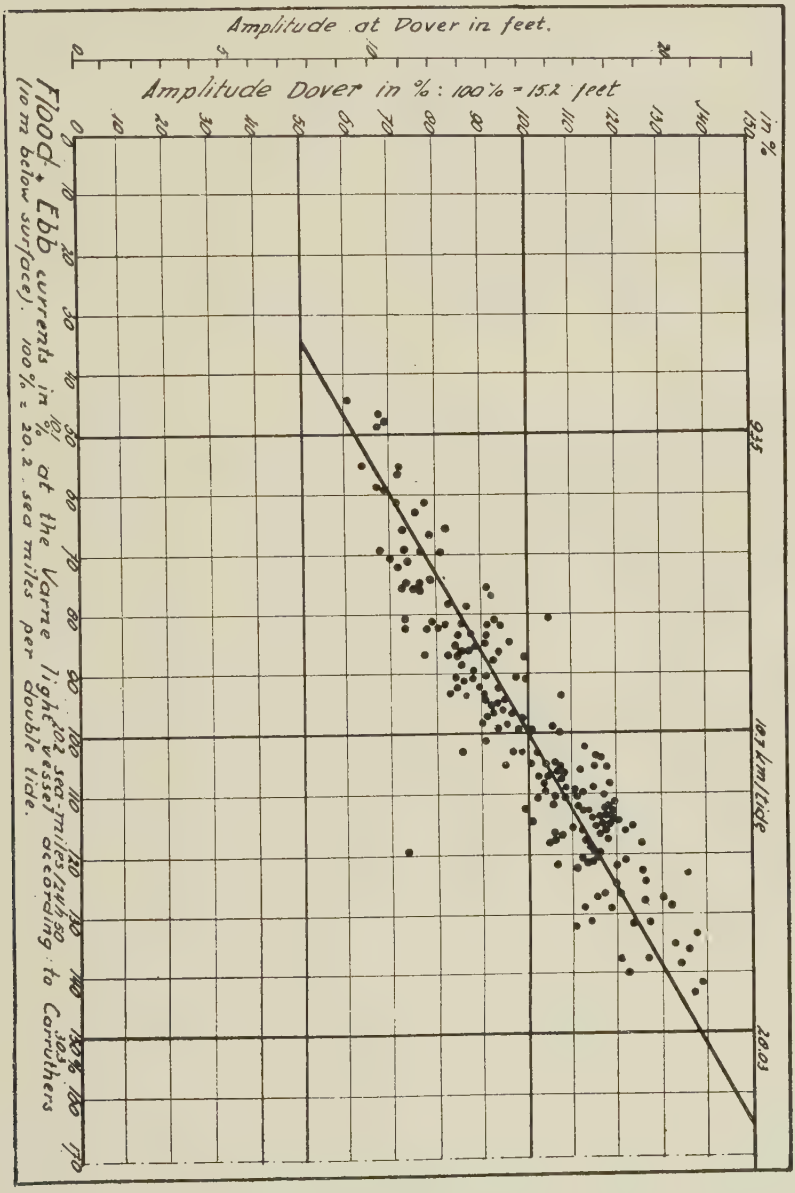


Fig. 12. Reduction graph portraying the relation between vertical and horizontal tide in the Straits of Dover.

We calculated this table from our measurement data of 1934—35, and for those of 1936 separately, and found exactly the same result for both. We also used Dr. Carruthers's measurements at the Varne[5]) and Sandettié lightvessels. All these calculations gave the same result, so that the table given above can be used with confidence for the streams in the area of the Straits of Dover.

It is interesting to add that this relation between the vertical tide and horizontal tide changes regularly towards the north in such a way that for Terschellingerbank the graph slopes quite differently, so that quite another reduction table results.

The use of the reduction table is that when any horizontal tide is measured, the streams during normal or spring or neap tides can be obtained immediately with a fair approximation.

Total Flow.

On 17th July 1935 we took echo-soundings in the alignment of the South Foreland and Gris Nez lights. At Gris Nez, light signals were given by which the "Oceaan" could be kept at distances less than 30 metres from the alignment. This was made possible by the use of a powerful mirror at Gris Nez belonging to the French Navy. This was rigidly fixed to shine in the direction of the lighthouse on the South Foreland, and, of course, the breadth of the "Oceaan" was known. When the ship was too much south short signals were sent out, and when she was too far north long signals were emitted, whilst an uninterrupted beam was shown when she was in position on the line. The soundings were made about 7 times per second, or thrice for every metre of depth. The entire operations lasted about 3 hours, and the results on a very small scale are given in Fig. 13.

The sea-levels were measured at Gris Nez and Dover. At the former place tide-manometers were used during several fortnights, while at Dover the well-known registering apparatus was employed. Assuming that the mean sea-levels for Boulogne, Calais, Gris Nez, and Dover were at the same height, we calculated for the period 14th June—5th August 1934 the zeros of the tide gauges.

At Dover zero	was	2·68 m.	below	M.S.L.
„ Calais	„	3·91 m.	„	„
„ Boulogne	„	4·92 m.	„	„

Mean sea-level is not, of course, half-way between high- and low-water levels, but is the level above which the area of the tidal curve is as big as it is below.

The total area of the profile Gris Nez—South Foreland was found to be 1,366,400 square metres at mean sea-level.

[5]) J. N. Carruthers. "The flow of water through the Straits of Dover as gauged by continuous current-meter observations at the Varne lightvessel." Fish. Inv. Series, Vol. XI, 1 and XIV, 4, London 1928 and 1935.

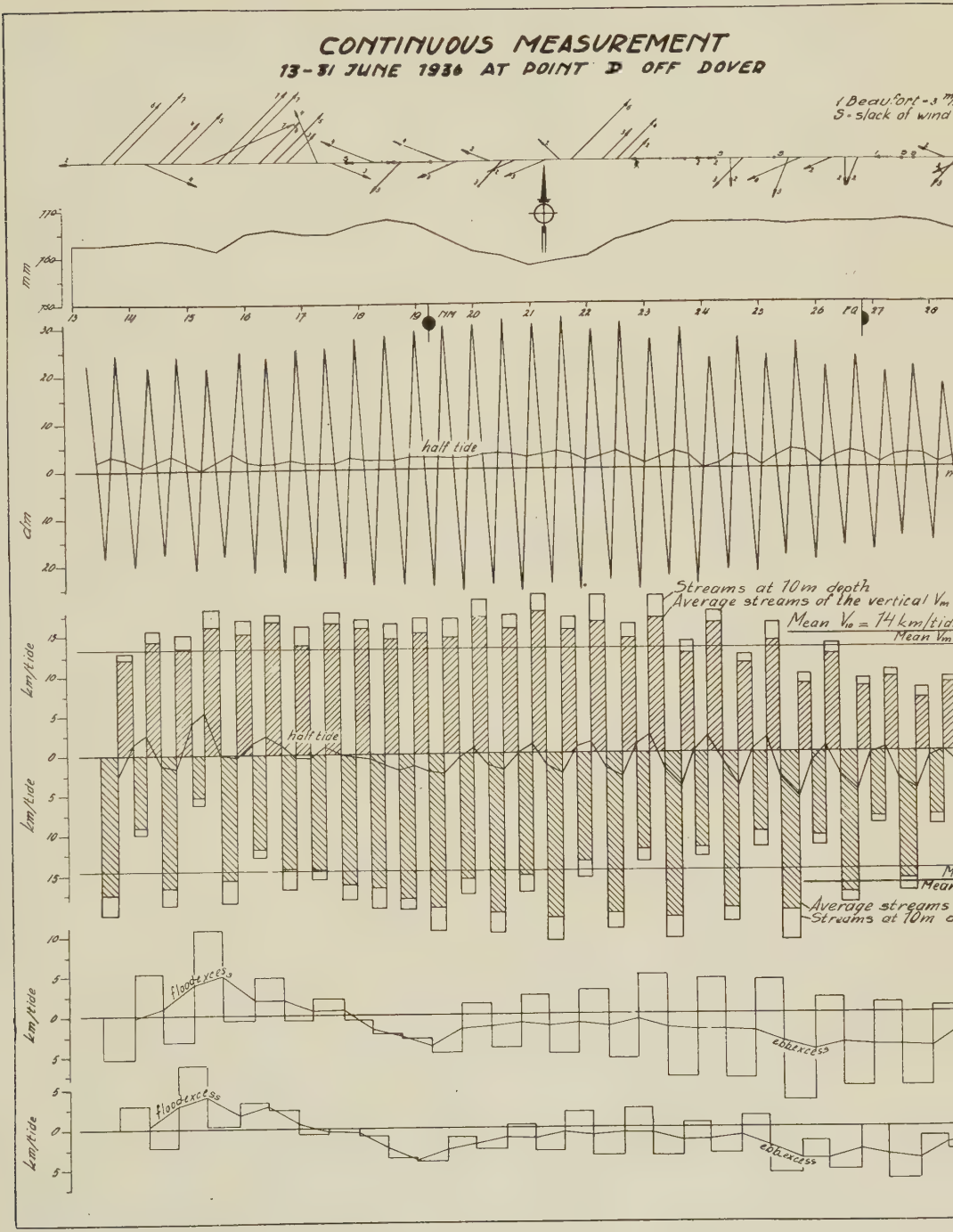
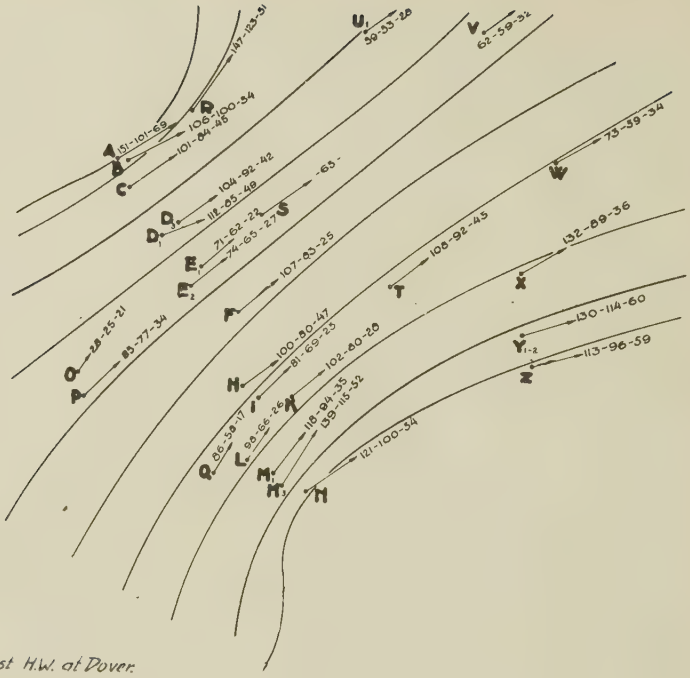


Fig. 13. Bathymetric section along the line Gris Nez—South Foreland from echo-soundings.

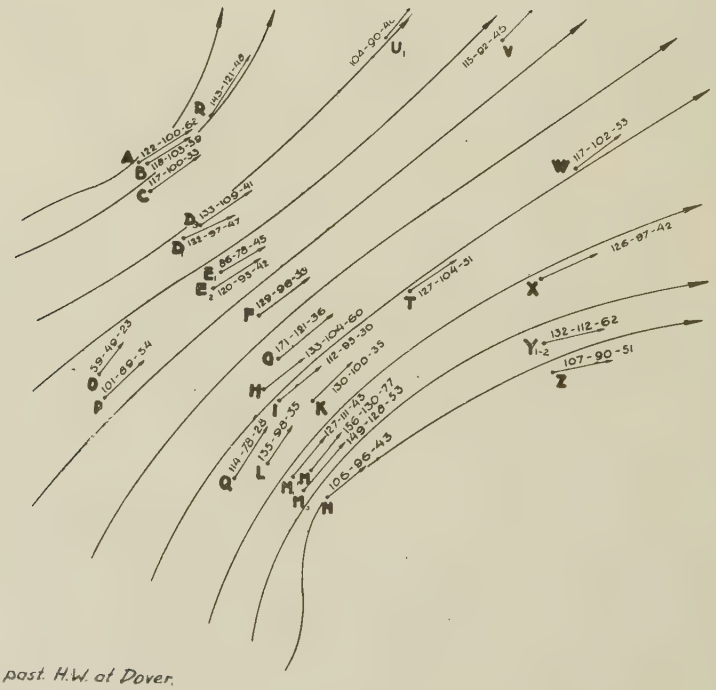
Fig. 14. Velocities (normal components) along the South Foreland—Gris Nez line from hour to hour.

a



0 Lunar hours past H.W. at Dover.

b



1 Lunar hour past H.W. at Dover.

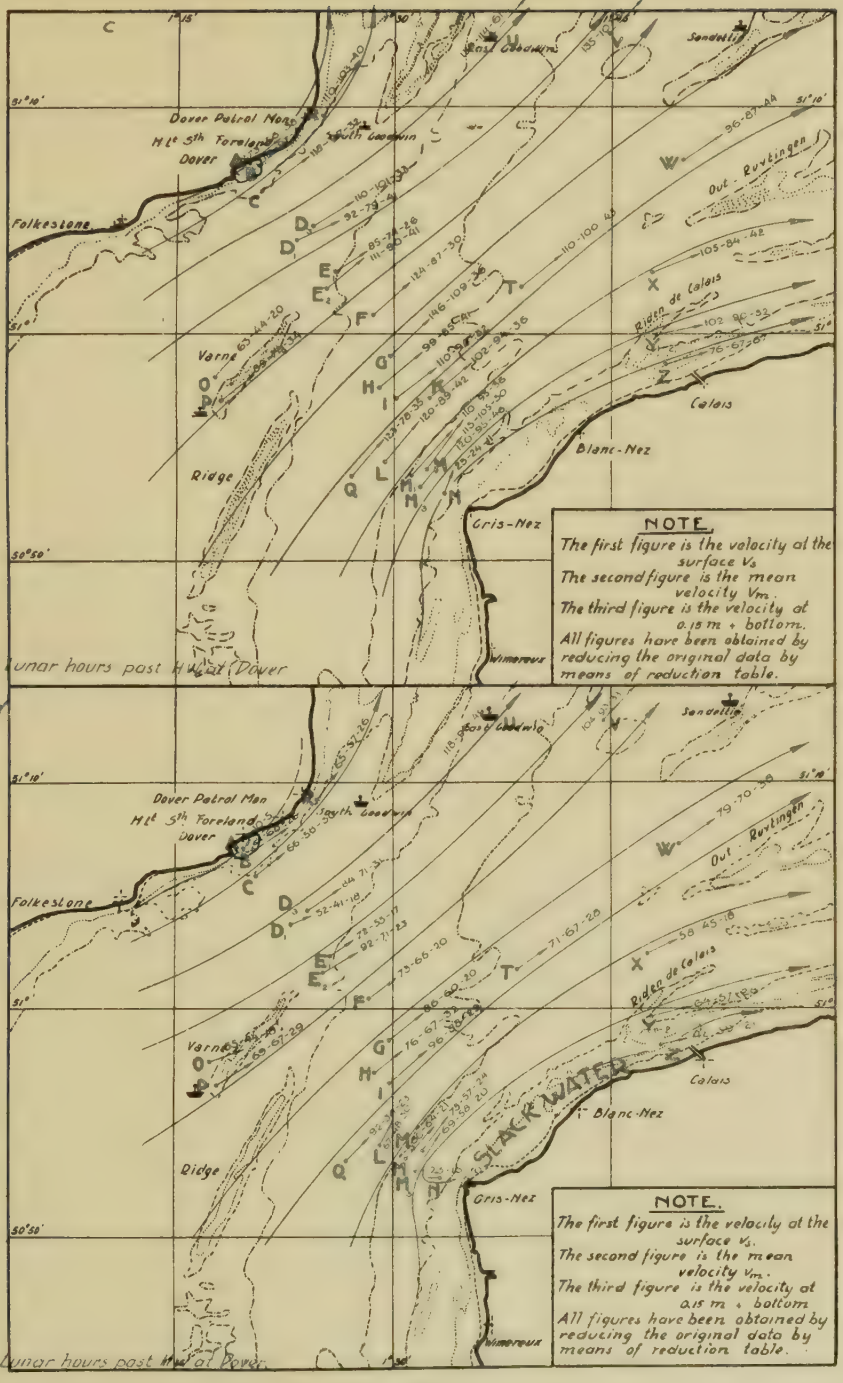
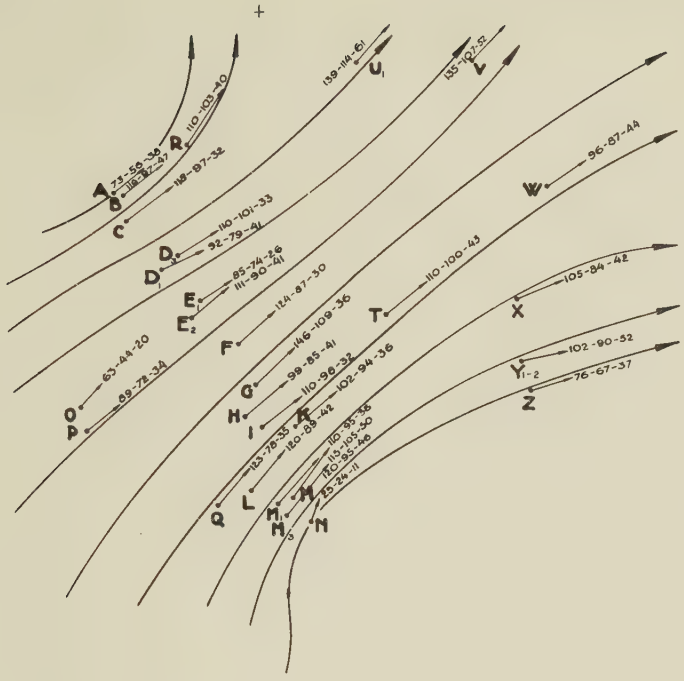
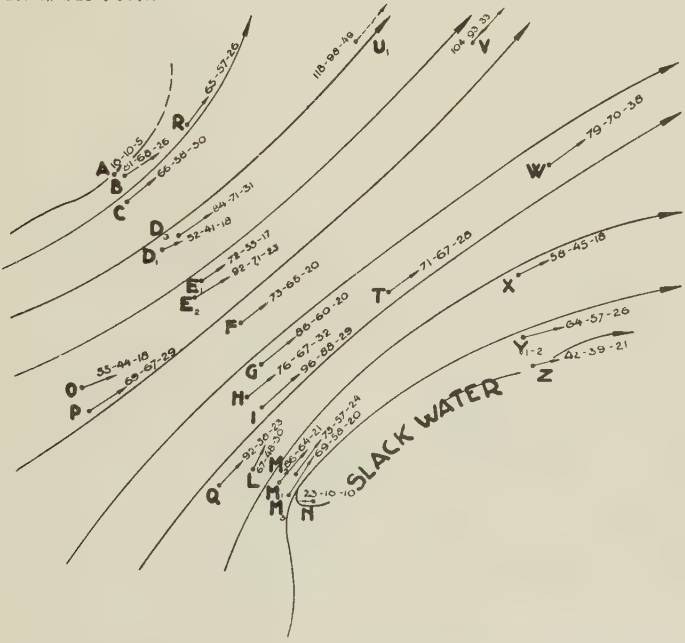


Fig. 16. Twelve charts showing, for an average tide, the speed of the streams from hour to hour with reference to Dover High Water.

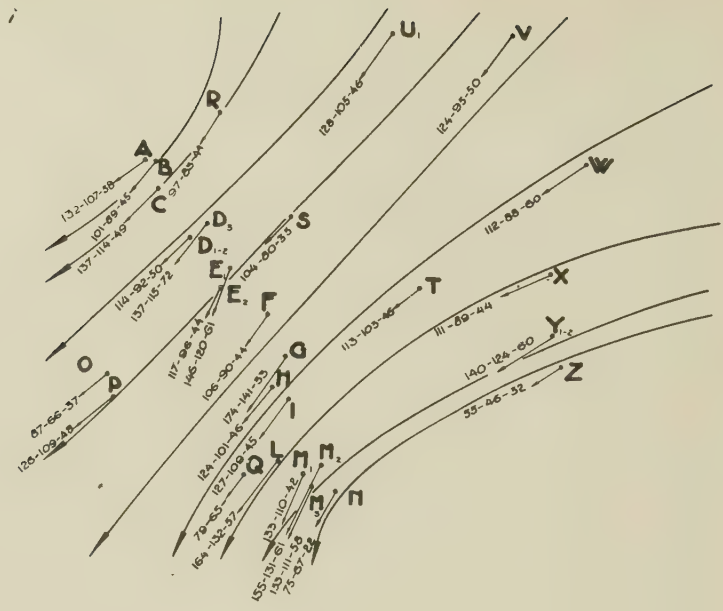
Fig. 16. Twelve charts showing, for an average tide, the speed of the streams from hour to hour with reference to Dover High Water.



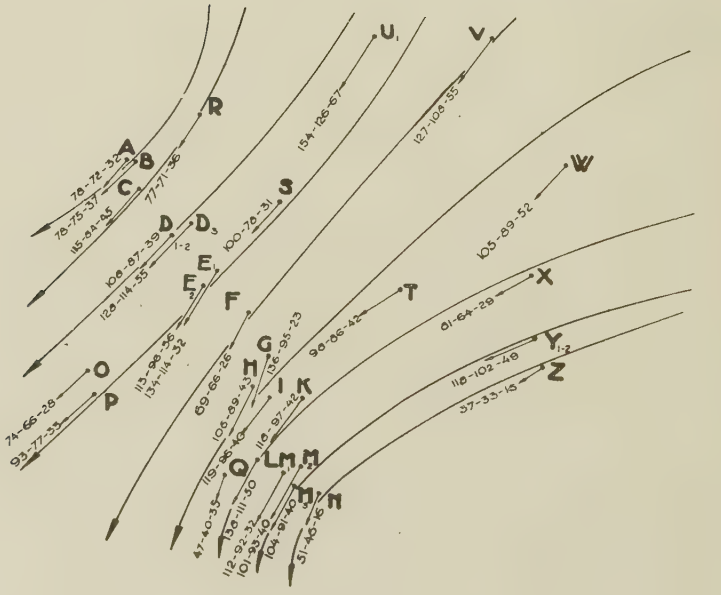
2 Lunar hours past H.W. at Dover.



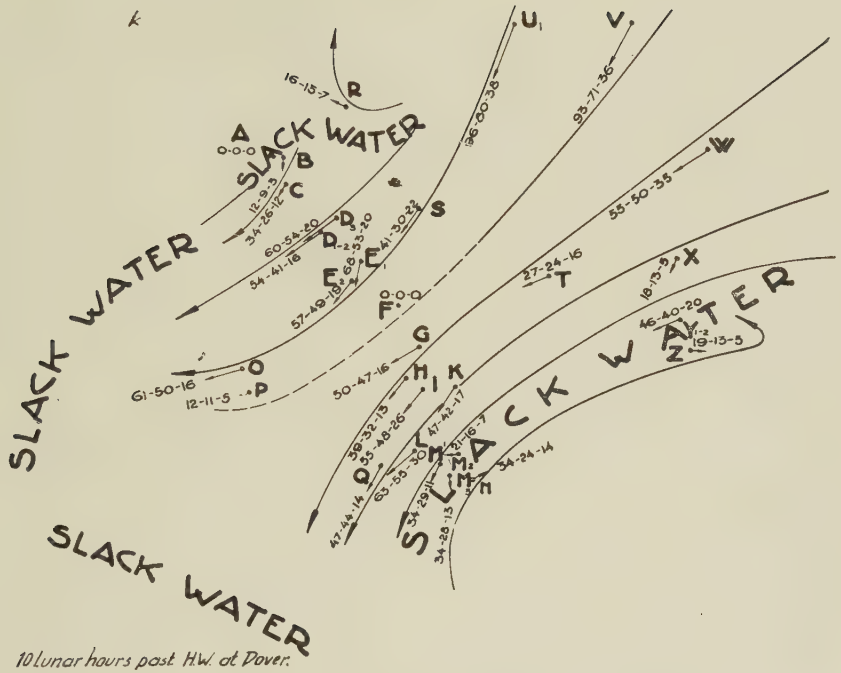
3 Lunar hours past H.W at Dover.



8 Lunar hours past H.W at Dover

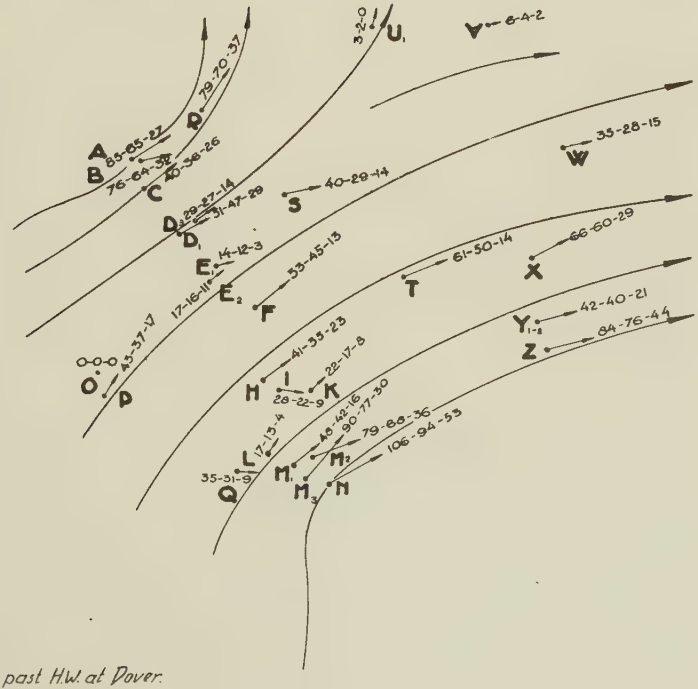


9 Lunar hours past H.W. at Dover.



10 Lunar hours past H.W. at Dover.

1



11 Lunar hours past H.W. at Dover.

It is noteworthy that we found the mean ebb-streams for the whole width to be faster than the mean flood-streams for the whole width whenever we measured under normal conditions. Only when the wind was blowing strongly from the south-west was a faster mean flood velocity found. The resulting drift (when expressed in terms of volume), which we found to be in the flood direction, was not due to velocity differences, but to profile-area differences. The average area of the profile South Foreland—Gris Nez is, during the flood-stream 8½ % larger than during the ebb-stream (see Fig. 15) and this must be one of the main reasons why a north-east-going drift exists in the Straits of Dover. According to our measurements the mean tidal streams are more or less in equilibrium when velocities only are concerned, except when storms (wind-effect or atmospheric pressure) cause disturbances.

Moreover, during the 16 days of continuous measurement in June 1936 at point D, the residual current was 1·35 kilometres per tide in the ebb-direction. This means that the mean V_m for flood was again lower than the mean V_m for ebb, V_m being the mean velocity of the whole water column. The total flood flow at D (in cubic metres) was, however, larger than the total ebb flow there, because the depths changed with the tides. Reckoning per kilometre width at point D, there was a transport of 428,000,000 cubic metres of water per flood tide and of 410,000,000 cubic metres per ebb tide.

Carruthers found the following relation for the drift in the four seasons:—

Spring: summer: autumn: winter = 77·8: 83·3: 100: 88·9. Therefore in autumn a larger amount of Atlantic water comes to the North Sea through the Straits of Dover than in the other seasons of the year. In consideration of these figures, 12½ % should be added to our measurement of the drift in order to obtain the annual average.

Without doubt the drift changes much according to different atmospheric pressures, or tidal circumstances, and I would not say that on repetition we should not find a greater volume of Atlantic water passing through the Straits of Dover owing to stronger flood-currents. At times the mean flood velocities may be stronger than the mean ebb velocities.

Consideration of Information from Drift-Bottle Experiments.

In the foregoing article we have set down the results of careful observations made with reliable instruments from a well-equipped ship. We have found the mean ebb-streams to be faster than the mean flood-streams to an extent that would imply a total water transport towards the English Channel, were it not for the consideration of changing depth with state of tide. Obviously, on occasions when drift-bottles pass through the Straits towards and into the North Sea, the flood-streams must be the stronger, at least at one part of the profile. It would be possible to show on reference to the results of drift-bottle

experiments carried out by Carruthers, of the Lowestoft Fisheries Laboratory, that in almost every week of two recent years, properly ballasted surface-floating bottles journeyed through the Straits from the Channel. They did so even whilst the observations reported upon above were in progress. We cannot possibly doubt that these drift-bottles indicated the drift rightly. An explanation is obtained on looking at Fig. 17. It is there seen that in the central part of the

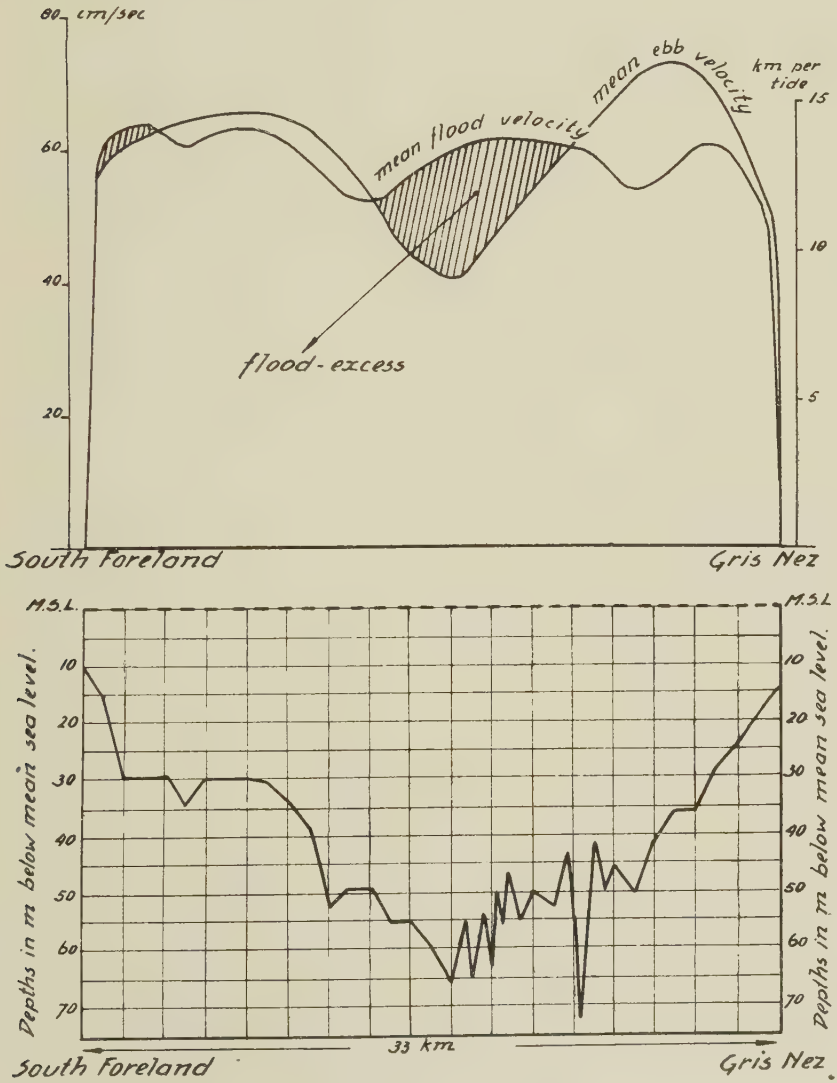


Fig. 17. Graph showing up-Channel and down-Channel drifts in the profile Gris Nez—South Foreland.

Straits of Dover the mean speed of the streams during the whole flood can exceed that during the whole ebb by as much as 20 cm./sec.; elsewhere there is an ebb excess. The figure refers to an aveage tide.

It is significant that the flood excess is in the central deep-water channel where we might expect the momentum of the flowing tide to be strongest. We are consequently inclined to assume that the drift-bottles of the Lowestoft Laboratory passed through the Straits more or less along the middle.

It would be interesting to organize another 16-day period of measurements at some point in the deep-water channel in order to confirm this explanation.

It should be added here that we know the Varne Bank to be composed of loose sand, and that very little change indeed has taken place there since 1848. This is in keeping with the results of our observations upon water movements as shown in Fig. 17.

In conclusion, I wish to express my thanks to Dr. J. N. Carruthers for checking the English of this paper.

Measurement of Submarine Daylight.

By

W. R. G. Atkins, G. L. Clarke, H. Pettersson, H. H. Poole, C. L. Utterback and A. Ångström.

Introductory.

OWING to the interest inherent in submarine light-measurements both to physical oceanography and to biology, the International Council for the Exploration of the Sea at its annual meeting in Copenhagen in 1935 decided to hold a special conference for the discussion of submarine light at its next meeting with a view to including such measurements in its future programme.

In order to have this subject thoroughly discussed, the Council extended invitations to Drs. W. R. G. Atkins and F. S. Russell, of Plymouth, G. Clarke, of Woods Hole, U. S. A., H. H. Poole, of Dublin, C. L. Utterback, of Seattle, and A. Ångström, of Stockholm, to attend the meeting and read papers. With the exception of Dr. Atkins, who was unable to attend, all the above-mentioned experts accepted the invitation, and at the meeting on 13th May 1936 the following papers were read:—

F. S. Russell: "Submarine Illumination in Relation to Animal Life";

H. H. Poole: "The Photo-electric Measurement of Submarine Illumination in Off-shore Waters";

G. Clarke: "Light Penetration in the Western North Atlantic and its Application to Biological Problems";

C. L. Utterback: "Spectral Bands of Submarine Solar Radiation in the North Pacific and Adjacent Inshore Waters";

A. Ångström: "On the Unit for Radiation in Oceanic Research".

In addition, Dr. Hans Pettersson, of Göteborg, read a paper on "The Transparency of Sea Water".

In the discussion after the papers had been read a number of hydrographers and biologists emphasized the importance of submarine light-measurements and the following recommendations were carried unanimously:—

1) That the lecturers and other specialists, before leaving Copenhagen, have a meeting for the purpose of preparing a plan relating to technical details, especially the degree of exactitude necessary in investigating the influence of light on plant and animal life in the sea.
2) That the plan be handed to the chairman of the Plankton Committee with a request that he undertakes to have a programme for further research prepared before the Council Meeting in 1937.

In accordance herewith the following experts met on Saturday, May 16th, under the chairmanship of Professor H. H. Gran:— Messrs. Ängström, Borley, Braarud, Bursa, Clarke, Farran, Höglund, Jacobsen, Jespersen, Matthews, H. Pettersson, Poole, F. S. Russell, Steemann Nielsen, H. Thomsen, Utterback.

A sub-committee was appointed for the purpose of drawing up definite proposals to be put before the next meeting of the Council, regarding methods and units of light and transparency measurements to be used in future routine measurements for biological purposes. The members appointed were Messrs. Ängström, Atkins, Clarke, H. Pettersson, Poole, and Utterback.

The following recommendations were made:—

1) It is recommended that measurement of submarine light for biological purposes should be carried out with instruments giving a sensibility of at least 10 Lux.
2) It is recommended that this sub-committee should co-operate with the International Radiation Commission.
3) It is recommended that the International Council for the Exploration of the Sea should arrange with Messrs Schott, of Jena, for standard blocks to be kept in reserve for supplying filters, coloured and neutral, and opals of standard properties and dimensions, according to specifications to be given by the sub-committee for Light Measurements.

By agreement with Dr. Ängström, president of the International Radiation Commission, the sub-committee, with the exception of Drs. Clarke and Pettersson who were unable to attend, met on 12th September 1936 during a meeting of the Commission at Oxford. In order to comply with the invitation from the International Council to collaborate in the deliberations of the sub-committee, the Radiation Commission appointed two of its members, viz., Dr. Mörikofer, of the Physical-Meteorological Observatory in Davos, and Professor Dr. W. Schmidt, of Vienna, to represent the commission at the sub-committee meeting.

At the meeting, Prof. Schmidt (who has since passed away) took the chair with Dr. Poole as secretary. The following resolutions were adopted:

1) In view of the possible importance played by fatigue effects and by curvature, we propose that a careful investigation of the same

should be made with various types of cells, preferably at some central institution equipped for such measurements. This investigation should be carried out under conditions approximating as nearly as possible to those under which the cells will be used.

2) We further propose that the methods for standardizing the photo-elements by means of solar radiation should be worked out in some localities suited for such work and, further, that diagrams and tables required for such computations should also be worked out.

3) The sub-commission asks Prof. Schmidt, Prof. Pettersson, Dr. Atkins, and Dr. Poole to draw up a scheme for simple measurements of submarine light with the aid of the chief methods now available.

4) We finally propose that the International Radiation Commission should seek to obtain from the Association of Hydrology of the International Union of Geodesy and Geophysics a subvention enabling the sub-committee to have the investigations proposed above carried out in the near future.

In accordance with resolution 4 above, Dr. Ångström, as chairman of the Radiation Commission, wrote to the president of the Association of Hydrology of the International Union for Geodesy and Geophysics applying for a grant of £ 200 from the Union for the purpose stated in resolutions 1 and 2 above, which letter was presented at the meeting of the Union in Edinburgh on 21st September 1936. Owing to all the Association's funds for the current year being already allocated, no monetary grant could at that time be accorded. The secretary of the Union, Dr. Proudman, in a letter to Dr. Ångström, expressed on behalf of the Union its keen sympathy with, and desire to aid, the proposed researches on submarine light-measurements.

Although the grant intended for financing work on standardization of photo-elements, i.e., of rectifying cells, by means of solar radiation was thus not obtainable[1]), a considerable part of the theoretical work necessary for the purpose has been carried out by Dr. Ångström. Valuable aid in this work has been given by Director Hoelper, of Potsdam. To both of these scientists the sub-committee is greatly indebted for their assistance.

The work of the sub-committee during the following months was carried out by correspondence between its different members. Finally, in order to work up the report in greater detail with a view of having it printed and submitted to members and experts of the International Council before its meeting in 1937, Dr. Pettersson was authorized by the Bureau of the Council to visit Dr. Poole in Dublin, where a draft report was drawn up at the beginning of April 1937. Owing to the desirability of having this report printed with as little delay as

[1]) According to a communication from Dr. Proudman a sum of £50 has recently been granted by the Union to Dr. Ångström for the purpose stated in resolution 2.

possible, time not permitting its being first submitted to all the members of the sub-committee, it was printed as a draft[1]) and distributed at the meeting of the Council in Copenhagen on 8th July 1937, when a vote of thanks expressing the gratitude of the Council to the members of the sub-committee was also passed. The present paper contains the revised report in its final form. A separate paper by Dr. Ångström on the standardization of photo-electric cells by means of sun radiation, included as an appendix in the draft report, will appear (with some additions) in a later issue of this Journal.

From the first it had been hoped that the deliberations of the sub-committee would lead to definite proposals for a standard equipment and a standard technique to be adopted by workers in the field belonging to the International Council, and also that a method would have been completely worked out for standardizing the photometers in energy units. It has, however, been found impossible to give at present such final advice on the highly complicated questions involved. The advent of rectifier cells has in many ways revolutionized the technique of illumination measurements, and necessitated the consideration of new instruments, e.g., galvanometers, for measuring the photocurrents. Since this and other modifications in the technique have only to a limited extent been tested for actual work onboard ship, it seems better to describe an equipment which is considered suitable for routine work for biological and oceanographic purposes, leaving to future experience the introduction of such modifications as may be found desirable.

It should be emphasized that the recommendations apply solely to routine measurements, probably carried out in the course of other work, for which it is highly desirable that the simplest and cheapest apparatus should be chosen. This of necessity imposes limitations on the range of results obtainable. Thus, the use of a highly sensitive galvanometer, such as used by Utterback, or the potentiometer method of Atkins and Poole, would enable measurements to be carried down to lower light intensities, or more exact determinations to be made of the spectral distribution by the use of filters transparent only to narrower spectral bands. The possible choice of filters may be widened by the use of a photometer case such as Utterback's, in which they are protected from contact with sea water. This may enable such gelatine filters to be used as possess the necessary permanence under exposure to light.

In view of the advance of our knowledge of the photosynthetic effects of different spectral regions, such exact knowledge of the spectral distribution under water is of growing importance, but for the present purpose the added complexity of the apparatus needed to obtain the more precise results might easily be a fatal objection. We may hope, however, that with the improvements in apparatus that

[1]) "Measurements of Submarine Daylight" by H. Pettersson and H. H. Poole with an appendix by Anders Ångström. Medd. fr. Göteborgs Högsk. Oceanogr. Inst., 13, 1937.

are reasonably to be expected, and with the experience gained with the simpler apparatus here considered, some, at least, of those making such measurements may be tempted to turn to the more elaborate outfits which will enable them to add to the precision, and hence to the value, of their results.

The Measurement of Submarine Illumination.

To physical oceanography, studies of submarine illumination have a twofold interest. They afford means for computing the rate at which radiant energy from the sun and the sky is absorbed and converted into heat in the uppermost layers of the hydrosphere, and, in this manner, for calculating also the ensuing rise in temperature. Secondly, the extinction coefficients resulting from such measurements give information as to the optical purity of the surface layers, and hence as to their content of suspended matter.

To biologists, the main interest afforded by such studies is connected with the photosynthesis by plants, the first step in the production of organic matter, i.e., of potential food-stuff, going on in the sea. There are reasons for believing that this production, which as regards microscopic algae, phytoplankton, is intensified during the spring increase of diatoms, may profoundly influence the survival of the larvae of the most important food-fishes, and hence also influence the quantity and quality of the catch of such fishes in subsequent years.

On the other hand, the vertical migrations of the zooplankton, and indirectly also of fishes preying upon this for their food, appear to be largely influenced by the light conditions. Finally, the amount of plankton and *detritus* suspended in sea water, especially in the stratified waters off the Scandinavian coasts and within the fjords, stands in a certain relation to the transparency of the water, which again can be inferred, either from measurements of submarine daylight or, more accurately, by direct methods to which reference will be made below (page 53).

Quantitative measurements of submarine light were made possible through the development of photo-electric cells. Thanks to the more recent development of the rectifying cells such measurements have of late been much simplified, and the cost of the necessary equipment has accordingly been reduced. There are, however, still so many errors possible in such measurements, which have to be avoided or else make corresponding corrections necessary, that, without a carefully worked-out routine, submarine daylight measurements will have mainly qualitative value only. The main purpose of this report is to discuss these errors and the necessary corrections, and to offer practical advice for the construction and use of measuring apparatus, and for its manipulation.

The use of rectifier cells of the selenium type appears to be the most satisfactory method at present (1937) available for the measurement of submarine daylight. Of these, considerable experience has

already been obtained of the cells supplied by Dr. B. Lange of Berlin-Dahlem and of the cells made by the Weston Instrument Co. Each of these possesses certain advantages which make it particularly suitable for certain purposes[1]).

In carrying out measurements the following aspects of the subject must be considered:— (1) Optical considerations (2) Electrical Equipment (3) Marine Equipment (4) Standardization (5) Method of making measurements at sea.

Optical Considerations.

The Use of Colour Filters. Selenium rectifier cells are sensitive over a range of wave-lengths extending beyond both ends of the visible spectrum. Their maximum is about 590 to 600 mμ. (that of the human eye being about 555 mμ.) and their sensitivities fall greatly towards each end of the visible spectrum, being in these regions, however, relatively much higher than that of the eye for the same wave-lengths. Thus a cell standardized in visual units in "white" light would greatly overrate both pure blue, and pure red light, as compared with visual estimations. For common illuminants the difference between the selenium and visual scales is far less, a source that is rich in red being generally poor in blue and *vice versa.* A cell standardized by means of a filament lamp appears, however, somewhat to underrate daylight.

The reading of such a cell exposed without a colour filter under water would not be a reliable index either of the visual illumination or of the radiant power, since the highly selective absorption of the water would cause the spectral distribution to vary with both the depth and the nature of the water. Moreover, the absorption of the less penetrating wave-lengths will increase the mean penetrating power of the residual radiation, so that, even in homogeneous water, we should be led to suppose that the lower layers were the more transparent.

It is accordingly advisable to limit the range of spectral sensitivity. For this purpose the following glass filters, each 2·0 mm. thick, appear to be the most suitable:—

(a) Where time permits only of a single series of measurements, Schott green filter VG9, giving with selenium cells a maximum sensitivity near 540 mμ. and an effective range from about 480 mμ. to 600 mμ.

(b) Where additional series can be made, Schott red filter RG1, which transmits freely above a sharp cut-off at 600 mμ., so that the upper limit is determined by the falling sensitivity of the cell, and may for daylight be taken as about 720 mμ.[2]); and Schott blue filter BG12, which with diffusing glass and a thick glass window may be taken as covering the range 360 to 480 mμ. with a maximum near 430 mμ.

[1]) The German "Electrocells" appear to resemble the Lange cells and will not be considered separately in this paper.

[2]) At 700 mμ. the Weston cell has about 12% of its maximum sensitivity and 4·4% at 760 mμ.

(c) Where it is desired to extend the measurements of blue or green below the depth attainable with filters, the cell may be used without a filter for the lower layers, comparative readings to be taken with and without the green filter at a depth near the limit for the latter. At this level the overlying water will have absorbed the red light almost completely, so that the ratio of the readings with and without the green filter is not likely to alter very much for greater depths. Thus readings without a filter may be used to extend the range by the use of a suitable correction factor.

The Use of a Diffusing Window. It is generally convenient to define the illumination at a given level as that falling on a freely exposed horizontal surface. A cell mounted behind a clear glass window will not give a fair measure of this, even in air, as the surrounding rim will cut off much low-angle light. When the photometer is submerged the error is even larger, as any rays in the water making an angle greater than 48·5° with the vertical will undergo total reflection at the inner surface of the window, and fail to reach the cell. We must accordingly use a diffusing glass outside the window in optical contact with the water. For this purpose the opal-flashed glass supplied by Messrs. James Hetley & Sons, 35 Soho Square, London, has proved very suitable, as it combines satisfactory diffusing properties with the minimum loss of light. The glass has polished surfaces, the diffusing layer being internal, so that the diffusing properties are not affected by immersion in water.

It is essential that this diffusing glass should be mounted *above* the colour filter, so as to ensure that the average obliquity of the light passing through the filter may be independent of the angular distribution of the incident light.

Reflection Losses. For measurements of daylight in air in fine weather it would be desirable to use a diffusing glass with a depolished upper surface, as this would avoid the increased loss of low-angle light caused by reflection from a polished surface. The transmitting and diffusing properties of a depolished surface are, however, entirely altered by the presence of water, so that is is useless for the submarine photometer at all times, and for the deck photometer in rainy weather. It is accordingly best to use opal glasses with polished surfaces on both photometers. This, unfortunately, causes the photometer to underrate the effect of low-angle light. If the photometer is standardized by means of light at normal incidence it will underrate the vertical illumination due to a uniformly bright sky, or that due to the sun at an altitude of 30°, by about 6%. The loss for high-angle sunlight will of course be less, and that for low-angle sunlight greater, but for most purposes in marine measurements we may neglect these differences, and treat the light in air as being purely diffuse, and when finding its intensity, multiply the photometer constant found for perpendicular light by 1·06.

We must, however, consider the effect on the upper surface of the opal glass due to the immersion of the submarine photometer in water.

We can avoid complications due to the lower surfaces (opal glass, filter [2 surfaces], and window) by keeping the intervening spaces always full of water. If we also keep a thin layer of water over the opal while comparing the submarine photometer side by side with the deck photometer, as is generally convenient, the total loss of light by reflection at the air-water and water-glass surfaces is rather less than at a single air-glass surface. Experiment shows, however, that the effect is nearly balanced by the increased loss of back-scattered light, so that in practice it is immaterial whether we work with the upper surface wet or dry. In either case the total loss of light in passing from air to glass exceeds that which occurs in passing from water to glass when the photometer is used to measure submarine light. This would make the submerged photometer read too high.

On the other hand, much of the light scattered back by the internal diffusing layer will undergo internal reflection at the upper surface of the opal, when the upper medium is air, and will return to the diffusing layer and contribute to its illumination, and increase the reading. In water this effect is greatly reduced. The reduction in sensitivity of the submerged photometer by the second effect more than compensates for the gain due to the first. Experiments showed that the readings of a photometer standardized in diffuse light, in air, needed to be multiplied by 1·09 when the photometer was submerged, in order to correct for the residual loss of sensitivity. This factor may be employed without serious error for any photometer of ordinary type fitted with a diffusing glass above the window.

Limitation of Maximum Illumination. The current generated by rectifier cells is not accurately proportional to the illumination, but falls below a linear relationship if the latter is large. This "curvature" of the characteristic, which increases rapidly with the resistance of the measuring instrument, is far more pronounced, for the same illumination, with Lange cells than it is with Weston cells. As, however, the Lange cell is some 3·5 times as sensitive, the discrepancy for equal photocurrents is much reduced.

Weston cells can be used under opal glass in full sunlight provided that the instrument for measuring the photocurrent has a resistance not exceeding 10 ohms, the curvature error for that intensity being then about 20 % in several specimens tested. As some specimens, however, show larger errors, and the determination of curvature errors at intensities approaching full sunlight is very difficult, it is well to reduce the necessary correction by limiting the illumination. When the cells are used under colour filters, no further screening is necessary, but when the deck photometer is used without a filter to measure the total incident light, the diffusing opal, which transmits some 40 to 45 % of light incident normally, may with advantage be replaced by a reducing neutral screen made either from a grey glass such as NG5 from Schott, or from plain glass covered by a semi-transparent layer of platinum according to the method of B. Lange. The transmission of this sieve should be about 4 to 5 %, i.e., about 10 % of that of the simple opal.

With the Lange cell a much greater limitation of illumination is essential, so that, even with colour filters, a reducing screen is necessary. Two similar screens, each transmitting about 4 to 5 % (10 % of plain opal), will be needed for use with colour filters on the deck and submarine photometers, and a third, transmitting about 1 % (2 % of plain opal) for use with the deck photometer for measuring total incident light. The screen on the submarine photometer must be replaced by a plain opal when it is desired to work at considerable depths, or in very turbid water.

Electrical Equipment.

Choice of Cell. Each of the two types of cell named possesses certain advantages. The behaviour of the Weston cell when exposed under opal to strong sunlight has been found to be quite reliable, such temporary fatigue or temperature effects as occur being smaller than the errors which are inevitable in most submarine measurements of daylight. The use of a screen on the deck photometer, when used without a colour filter, does not complicate the work, and is advisable in order to reduce the curvature correction, which varies from cell to cell and should always be determined. As no sieve is needed in the submarine photometer there is no need to haul the photometer onboard in the course of a series, which is often a great advantage, as it is desirable that each series should be completed as quickly as possible.

The Lange cell is some 3 or 4 times as sensitive for the same area, so that measurements can be made in deeper or more turbid water with the same galvanometer equipment, or for similar light conditions a less sensitive and cheaper galvanometer may be used.

Measurement of Current. The choice of a suitable instrument to measure the current presents certain difficulties, as it must, as far as possible, satisfy the following conditions, some of which are mutually opposed.

(1) It must be capable of use onboard ship in the worst weather conditions under which it is desired to make measurements.

(2) It must have as low an effective resistance as possible, at least when used for measuring currents above 100 μ.-amperes.

(3) It must have the greatest possible current sensitivity.

(4) It must be capable of as quick reading as possible, and be easy to use.

(5) It should preferably be as simple and inexpensive as possible.

Where the greatest possible sensitivity is needed the potentiometer method using the modified Campbell-Freeth circuit is possibly the best. It is unaffected by the motion of the ship and has zero effective resistance on all ranges. A measurement can be made in a few seconds to within about 5×10^{-10} amperes, if necessary, with comparatively steady light, but the method is not suitable for measuring a rapidly fluctuating light, such as occurs just below a rough surface.

The chief drawbacks of this method are that it is somewhat

exacting to use, and the apparatus is rather complex and expensive. For general work a galvanometer is probably preferable. Experience of galvanometers suitable for use when the ship is rolling appreciably is limited. The following instruments would appear to be suitable.

Inexpensive pointer galvanometers of small size and with moderately high resistance may be used provided care is taken to limit the maximum illumination reaching the cell. Instruments specially designed for use with the Lange cell, made by Siemens, of Berlin, giving a full deflexion of 100 scale-units for a current of 45 micro-amperes and provided with an internal shunt reducing the sensibility to one-tenth, have been used onboard ship in a moderate swell with good results. With a simple opal before the Lange cell one unit on the higher sensibility range corresponds to an illumination of about 2 Lux. The resistance, about 750 ohms, is somewhat high, but the shunt used for the higher range of light reduces this to about 75 ohms. Owing to the small size of the instrument it can easily be mounted on gimbals, should this be necessary through the conditions of work. If used with a Weston cell behind opal and colour filter but without reducing screen, an external shunt further reducing the sensibility and the resistance to 1/3 would have to be used with this instrument.

Wherever a high sensibility is desired the use of a light-spot galvanometer, preferably one having a low internal resistance, seems advisable. An instrument of this type made by Siemens of Berlin, having an internal resistance of about 20 ohms and giving a sensibility of about 30 scale-units for one micro-ampere, has been used with good results onboard the Swedish research ship "Skagerak" for some years. With a moderately rough surface the zero varies over a few scale-units only. In order to extend the range of the measurements extra shunts of 1:3, 1:10, 1:30, 1:100, and 1:300 can be obtained with the instrument.

Other light-spot galvanometers are made by Leeds and Northrup, Philadelphia, by Tinsley and Co., South Norwood, London, and by the Cambridge Instrument Co., 45 Grosvenor Place, London S.W.1. Of these, the first-named instrument has been used extensively onboard ship and in the open sea by Utterback with satisfactory results, but its adjustment requires some expert handling, and it can therefore hardly be recommended for routine work. The Tinsley galvanometer is especially constructed for work under very exacting conditions (onboard battleships in action) and under very rough conditions it is probably equal, if not superior, to other light-spot instruments, but it has so far not been in actual use for submarine light-measurements.

The Cambridge light-spot galvanometer appears in its present shape unsuitable for work onboard ship, but the maker states that improvements in this respect are now being made.[1])

All the light-spot instruments mentioned above cost about £30 to

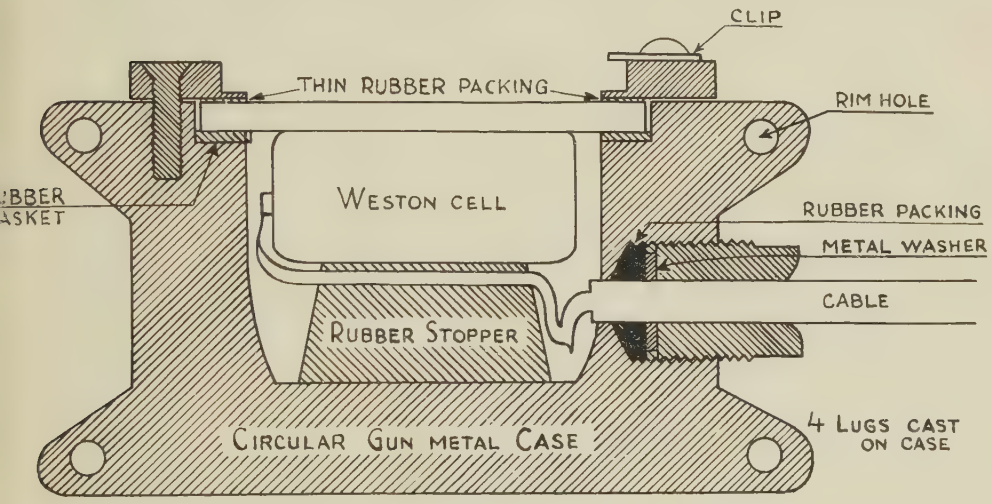
[1]) With a galvanometer giving, say, 15 scale units for 1 micro-ampere a typical Weston cell 40 mm. in diameter will give under opal about 1 scale-unit per Lux. A Lange cell of the same size should give 3 to 4 scale-units per Lux.

£35 without extra shunts, with the exception of the Cambridge galvanometer, which in its improved condition is stated to cost about £12. The pointer galvanometers mentioned above are much less expensive, the price being at present £5 to £6.

Whenever the light-spot galvanometers are used onboard ship, they should be placed on rubber sponge so as to reduce the effect of tremors from the machinery.

Marine Equipment.

Photometer Case. This must evidently be absolutely watertight under all conditions of use, and strong enough to withstand the rough treatment that it is likely to receive in bad weather. It should be as compact as possible, so as to offer the minimum resistance to the lateral



Scale 2: 3.

Fig. 1.
Section through suggested photometer-case

motion through the water that is often unavoidable. It must be readily capable of suspension with the window horizontal, and to ensure this, when the ship is drifting or anchored in a current, should have provision for the attachment of a lead sinker. It is also highly desirable that the bottom should be flat, so that the case can be placed on the deck when it is swung aboard, and comparisons with the deck photometer readily carried out on shore, or in smooth water, by placing both side by side on a level surface.

The metal rim surrounding the window should be deep enough to hold the filter and opal glass, and, to prevent appreciable shading of low-angle light by this rim, it is well to make the window somewhat larger than the cell. This window must, of course, be strong enough to withstand the hydrostatic pressure at the greatest depth reached.

It is particularly important that there should be no possibility of light reaching the cell past the edge of the filter, which, however, must be instantly removable.

Figure 1 shows a type of case suitable for use with either kind of cell, and satisfying the above conditions[1]). This is a circular gun-metal casting, which can be chucked in a lathe for machining the necessary surfaces, and is designed for use with opal and filter 8·0 cm. in diameter.[2]) The inner rim, on which the filter rests, prevents leakage of light, while the outer rim is deep enough (6 mm.) to retain the opal on the top of one 4 mm., or two 2 mm., filters, if required. Three clips on this rim hold the opal from falling out if the cell is tilted or inverted.

It is well to use a thin and narrow metal ring nearly 8 cm. in diameter (say of wire 0·5 mm. thick) as a distance piece to separate the opal from the filter. This facilitates the filling of the interspace with water devoid of air bubbles.

If a Weston cell is used, as shown in the sketch, the projecting terminals must be cut off short, care being taken not to damage the cell in any way, and a piece of thin wire soldered to each. These wires pass under the cell and are soldered to the ends of the twin cable. If one of these wires is of iron and the other of copper they will constitute a little galvanic cell, should water leak into the case, and thus by greatly increasing the current give warning in time to save the cell from destruction. The cell may be mounted on a rubber stopper cut to such a height as to keep the cell rim pressed against the glass window, and held in a central position by rubber-sponge packing. Care must of course be taken to prevent the possibility of the connecting wires touching the case.

The connecting cable should be good quality cab-tyre, round, twin flex, the sectional area of each stranded conductor being not less than 0·5 sq.mm. This will have a resistance of about 7 ohms per 100 metres of twin cable. The joint in the screw gland is made with a piece cut from a rubber stopper, and that round the window with a rubber insertion gasket. Both rubber packings may be smeared with vaseline before screwing up.

The bridle supporting the photometer is shackled to the two upper eye-holes. As these are in the plane of the cable a twin bridle is sufficient to ensure that the photometer hangs level. It is easier to adjust than a triple one, and causes less obstruction of light. It is made of thin galvanized steel-wire rope and may conveniently be one metre long to the lashing at the top, so that one can see at a glance when the window is 1 m. below the surface. This facilitates the setting of the meter block.

---

[1]) A photometer case designed for use with the Lange cell has been described in an earlier publication, see H. Pettersson and S. Landberg "Submarine Daylight", Medd. fr. Göteborgs Högsk. Oceanogr. Inst., No. 6, K. V. V. S. Handl., Ser. B. Bd. 3 (1934).

[2]) With the Lange cell mounted in a suitable photometer case, opals and filters measuring 49 mm. in diameter are used.

It is most important that the electric cable should be lashed to the top of the bridle to prevent strains on it from tilting the photometer, or causing trouble at the gland or inside the case.

A lead sinker weighing 10 to 15 kg. should be hung from the two lower holes. It is best to give this an elongated streamline form with a tail fin, and hang it horizontally by two wires, one from each hole in the case, making suitable adjustments to ensure that the window is as nearly as possible horizontal. This arrangement offers the minimum resistance to lateral motion, and prevents the rotation of the photometer, which, by twisting the cables, may cause serious delay in hauling the photometer on board.

As alternatives to the usual position the photometer may be hung inverted or with the window vertical. For inverted working the sinker should reflect as little light as possible, and should be hung at least a metre below the case. For normal working with the window upwards a less depth may be more convenient.

Deck Photometer. Unless it is proposed to work during heavy rain no extra protection is required for the deck cell beyond the opal window or sieve and the colour filter. As it is essential that no light should reach the cell past the edge of the filter, this and the overlying opal should be considerably larger than the cell and, for the Weston cell, they should not be less than 6·5 cm. in diameter. It is advisable to rub the rim of the cell case with emery paper to remove the raised lettering, so as to allow the filter to make a better joint with it.

The window must be horizontal, and a gimballed support is advantageous. The cell is mounted in some position as free as possible from all shading, but sufficiently accessible for the rapid changing of the filters.

General Equipment. The galvanized steel supporting rope should be as thin as is consistent with adequate strength, in order to reduce lateral drag. The supporting sheave should be attached to a well-stayed spar projecting over the stern on the centre line of the vessel to a distance equal to, say, twice the height of the ship's rail above the water. A greater distance is desirable to reduce shading, but may prove impracticable or inconvenient in bad weather. The spar, while stiff and strong enough to withstand the considerable stresses caused by pitching, should cause as little shading as possible.

The block used for measuring the depth should be capable of reading to a fraction of a metre, and must be correct for the size of wire rope used, since a difference of 0·5 m. in depth, even in comparatively transparent water, involves a change in illumination of 5 to 15 per cent.

Standardization of Photometers.

For many purposes it is sufficient to be able to state the submarine illumination as a percentage of the surface light in the same spectral band. This is all that is needed in order to find the transparency of the water to light of that colour, and from these percentages and a

knowledge of the spectral intensity of daylight commonly occurring under the given conditions of season, time, place, and weather, we may find the corresponding average submarine illumination of that colour. To find these percentages we only need to know the relative sensitiveness of the deck and submarine photometers, and their respective curvature corrections.

It is evidently desirable, however, and it may be necessary for some purposes, to be able to obtain results in definite units, and it would be desirable to express them in terms of the radiant power, say in milliwatts per square centimetre, or gram-calories per minute per square centimetre in the given spectral bands.

Until the standardization of cells with filters in energy units, either by the solar method suggested by Ångström[1]), or by the use of a source of known colour temperature, has been more fully worked out, it seems advisable to employ some definite (though arbitrary) unit, in which to measure the illumination as recorded by the cell with and without the various colour filters. When the cell is used with plain opal but without a colour filter we may call this unit the "Lux", although we must remember that it will differ somewhat from the true Lux, as estimated on the visual scale. On the other hand, the use of the term Lux for a light-intensity unit measured by the cell with a colour filter is entirely misleading, so we may content ourselves by expressing the readings of the selenium cell with opal and the colour filters RG1, VG9 or BG12 in "red" units, "green" units, or "blue" units respectively.

One "red" unit will represent the red light, i.e., the radiation between 600 and 720 mμ. in a total white illumination of 1 Lux as supplied by the standard source, with similar definitions for the "green" unit, 480—600 mμ., and the "blue" unit, 360 to 480 mμ. The red, green, and blue units will be readily convertible into radiant power, say in gram-calories per square centimetre, in the corresponding spectral bands, as soon as the energy standardization has been effected. Since it is absolutely essential that the units agreed upon should really be comparable *inter se*, we suggest that the standardization of cells with their appropriate colour filters and reducing screens should be carried out in some central physical institution, preferably in Copenhagen.

The choice of a standard source presents certain difficulties, as it is not easy to combine the following requirements with the qualities of constancy and reproducibility needed by all photometric standards.

(a) If the standardization is to be carried out in terms of visual units the spectral composition should closely resemble that of average daylight; if in terms of radiant power, the colour temperatures should be accurately known, and as high as possible.

(b) It is highly desirable, at least, that the standard should be capable of providing an intensity of illumination of the same order as that which the cell will be used to measure, thus reducing the

[1]) Ångström, A: On the Standardization of photoelectric Cells by Means of Sun Radiation. Statens Meteorol.-Hydrogr. Anst. Meddel., Ser. Uppsatser No. 20.

importance of curvature correction, which must in any case be determined over the range of illumination to be covered in use, say by the use of a projector-type filament lamp run at constant voltage and a photometer bench.

As possible sources we may consider:—

1) the standard filament lamp;
2) artificial mean noon sunlight obtained with such a lamp and the Davis-Gibson double liquid filter;
3) the carbon arc.

Of these the filament lamp, though otherwise satisfactory, suffers from the lowness of its colour temperature compared with daylight, if it is to be used under conditions for which its constancy is sufficient. The ordinary sub-standard uni-plane filament lamp is, moreover, incapable of providing an intensity of more than a few hundred Lux. This low intensity involves very accurate knowledge of the curvature correction.

If the Davis-Gibson filter is used with such a lamp we can obtain a source closely resembling mean noon sunlight. This is probably the most satisfactory source at present available for standardizing selenium cells in visual units, but the available intensity is further reduced, probably to well below 100 Lux.

The carbon arc appears at first sight to be a most unsatisfactory standard, but with due precautions its unsteadiness can be overcome and it combines the valuable properties of high (and probably fairly constant) colour temperature with high intensity and easy reproducibility. Under suitable conditions the visible light from the positive crater appears to be directly proportional to the current, but the ultraviolet light from the arc itself is more variable. Radiation from the hot carbon outside the luminous crater renders it difficult to estimate the proportion of the total radiant power that occurs in any given band of the visible spectrum, so that the carbon arc does not appear to be a suitable source for standardization in power units.

Whatever source is ultimately chosen for use in the central institution should be employed there for the standardization of the deck photometer with and without the various colour filters, curvature correction over the required ranges being found at the same time by photometer tests with an intense source. The resistance of the measuring circuit used in these standardizations must be the same as that employed in the routine work. The limits of curvature error, as stated by the makers of the cells, should also be checked in the course of the standardization. Until more evidence has been accumulated regarding the constancy of selenium cells with time, we advise that this standardization of the cells should be repeated at not too long intervals, say, of one year.

Comparisons between the deck photometer and the submarine photometer are part of the routine work and will be dealt with in the following section. Any notable changes in the relative sensitivities of the two cells found by this comparison indicate a change in one or both of the cells.

Method of making Measurements.

The surface light is almost certain to vary during the course of a series of submarine observations. The most convenient method of stating the results is accordingly to give the light at any depth as a percentage of the surface light at the same moment. We therefore start by comparing the two photometers side by side on a level surface freely exposed to the sky, each under its own colour filter and opal or reducing screen, according as the Weston or Lange cell is used, and thus we find the ratios of the sensitivities of the two photometers for red, green, and blue light, respectively. The spaces between the window, filter, and opal or reducing screen on the submarine photometer should be filled with water during this comparison.

As the deck photometer has been standardized in "red", "green" and "blue" units, we can find the light intensity in these units at any depth. We must remember, however, that the photometer is standardized in perpendicular radiation, and that the obliquity of average daylight will increase the reflection losses at the upper surface of the opal, and so reduce the sensitivity. The average obliquity will depend on the altitude of the sun, and on the proportion of sunlight and sky light, so that the correction factor varies according to the conditions. It is sufficiently accurate for most marine measurements to multiply the constants by an average factor, 1·06, which corrects for the reflection loss for light from a perfectly uniform sky or from the sun at 30° altitude.

When the sun is shining, it is as well to take, when possible, a reading of the diffuse light by screening off the direct sun with a small object held a couple of metres from the cell. Care should be taken to avoid unnecessary screening of sky light. The ratio of the total to the diffuse light gives a convenient index of the relative intensity of the sunlight. Time will not permit of these diffuse light measurements during the course of a submarine series, but it is well to make them at the beginning and end.

When making submarine measurements alternate readings of the two photometers are made as quickly as possible, say at least two of the submarine cells with one of the deck cells interposed. The depth is then changed, and the readings repeated. Rapidity of work is important to minimize the effect of changes in the light or in the water (due to tidal currents or the drift of the ship), but it is usually possible to work on days of variable light by increasing the number of readings at each depth, and either averaging a number or selecting a set for which the light has remained constant. This, of course, slows down the work. The time of each set of observations should be noted.

It is seldom worth while to attempt readings at less than 1 m., except in very smooth water. The intervals chosen for greater depths must depend on the opacity of the water, the colour of the filter used, and the time available. One should aim at not less than 5 levels in each series. For reasonably clear water readings at 1, 5, 20, 35, and 50 metres might be suitable for the blue and green filters, and at 1, 5, 10,

15, and 20 metres for the less penetrating red light. In stratified coastal water a larger number of levels is generally desirable.

Below 20 m. the red light becomes almost inappreciable, and the residual radiation consists chiefly of the most penetrating part of the spectrum. This is in the green for coastal, and the blue for oceanic waters. We may extend the depth range of whichever band proves to be the more penetrating by removing the filter from the submarine photometer and comparing the "percentage readings" with and without filter for the greatest depth for which the former are sufficiently large. We thus obtain the necessary reduction factor for use with the cell without filter at greater depths. The colour filter should be retained on the deck cell.

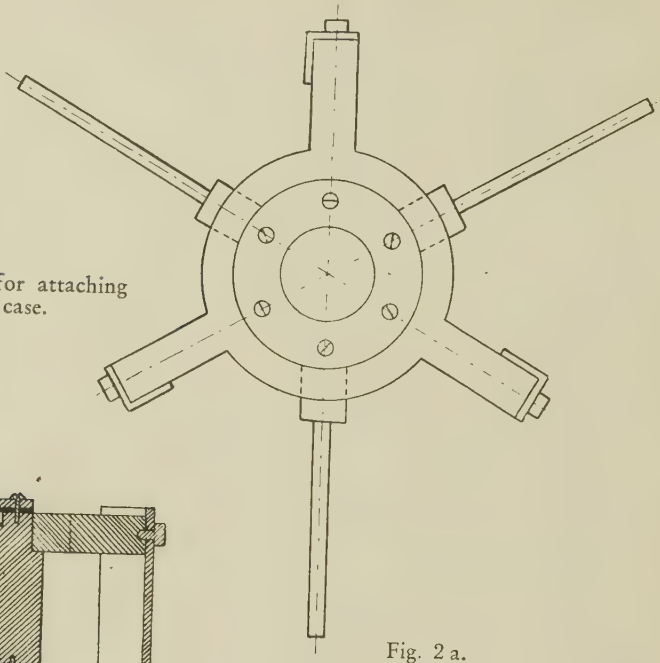
Care should be taken that the photometer is always clear of the direct shadow of the ship. If this is done it does not appear likely that the shading error will ever exceed a maximum of some 10 %, reached at a moderate depth below the surface, decreasing with further increase of depth. The magnitude of this error in any particular case will depend on the dimensions of the ship, the distance outboard of the point of suspension, and the relative proportion of direct sunlight and diffuse light, a larger proportion of which will be cut off.

It is also important to note approximately the angle made by the supporting cable with the vertical, since if the ship is drifting fast and this angle is large, an appreciable error is introduced in the estimate of depth. An angle of 10° represents about a 1 % error, 20° a 4 % error, and so on, the error being approximately proportional to the square of the angle of inclination.

Measurements of the Transparency of Sea Water.

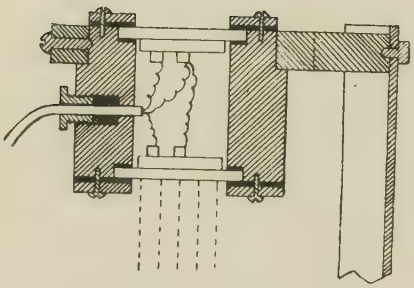
Although values for the transparency of sea water can be easily found from measurements of daylight in different depths, there are certain limitations inherent in this method which make it desirable to measure the transparency of different water-layers *in situ* by a direct method.

Since the transparency of sea water, especially where it is stratified, as in Scandinavian fjords and off-shore waters, may vary very rapidly with depth at certain levels, e.g., near density boundaries, it is necessary to make measurements in very many depths, or still better, continuously. This, of course, is extremely laborious when daylight is used and, moreover, two such measurements at different depths enter into the computed value for the transparency within the intervening column. Further, daylight measurements can only be carried out in depths where the residual light has an easily measureable intensity and are thus more or less severely limited, according to the conditions of surface light, e.g., time of day and meteorological conditions. Especially in northern latitudes in winter the surface light may be so poor that transparency values, except in the very uppermost layers, are unattainable. The same applies to conditions where there is a very turbid surface-layer, or under ice, especially when this is covered with snow.



Detachable ring for attaching projector case.

Fig. 2 a.



Top view of photometer case.

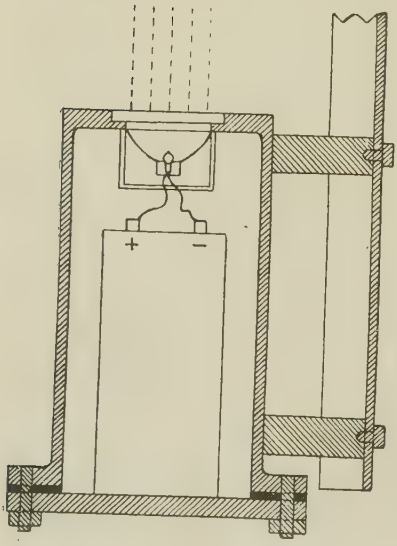


Fig. 2 b.

Combined daylight and transparency meter with lamp-case attached. Scale 1:4.

Apart from this, daylight being to a large extent already diffuse, the loss in intensity through scattering from suspended particles is largely compensated through back-scattering, whereas if a directed beam of artificial light is used, no appreciable back-scattering takes place and the presence of intervening particles is, therefore, much more effective in reducing the intensity of the light.

An instrument designed for measuring the transparency of sea water *in situ* to a slightly diverging beam of electric light impinging on a Lange cell after passing twice through a column of water 1 metre in length has been described elsewhere[1]) and results obtained with it are given. These prove that even small variations in the transparency of the water with depth, imperceptible to daylight measurements, can be discovered by means of the transparency meter, and that the presence of clouds of suspended particles, occurring at certain levels, can easily be localized by letting down the transparency meter with its lamp alight and watching the continuous changes in the photocurrent from the exposed cell.

In order to obtain transparency values in a similar manner with as little delay as possible a combined instrument for measuring daylight and transparency has recently been constructed and is described below.

The Combined Daylight and Transparency Meter.

The instrument consists of two main parts, the photometer and the light-projector. The former is a modified submarine photometer case which can be used for measuring the vertical illumination on a photometer turned upwards in the usual manner, whereas a second cell mounted below the first and turned downwards measures at the same time the daylight penetrating upwards through the water, a 3-stranded cable and a switch allowing the operation of the two cells in rapid succession. The second cell thus does the same service as the photometer described in an earlier paragraph when used inverted.

The projector, which can be very easily attached to the photometer case by means of three L-shaped steel girders, consists of a pressure-proof and watertight case containing a 2·3 volt Nife storage cell of 13 amp-hours capacity and a small electric torch with a chromium-plated reflector. By means of a small mercury contact the lamp is kept burning only when the projector is in the working position, i.e., with the lamp facing upwards. The beam of light sent out through a pressure-proof window then passes through the intervening column of sea water, 1 metre in length, before impinging on the downward cell through the lower photometer-window. With the projector in position the photocurrent from the same cell thus gives a measure of the transparency of 1 metre of sea water, which can be read alternately with the photocurrent produced in the upper cell through daylight.

Before and after each series of measurements the deflexion produced

[1]) See H. Pettersson, A Transparency-Meter for Sea-water, Medd. fr. Göteborgs Högsk. Oceanogr. Inst. No. 7, K. V. V. S. Handl. B. 3 (1934).

by the lamp-light alone in air (with the instrument carefully screened from diffuse daylight) is measured with both windows well dried and cleaned. Corresponding to the slight decrease with time generally observed in the photocurrent, due to the gradual fall off in the voltage of the storage-cell, corrections are made in the intervening values measured in the immersed condition.

In order to find from such measurements values for the extinction coefficients to electric lamp-light within the water where the measurements have been made, one may use the approximate formula:—

$$I = 1{\cdot}9 \times I_a e^{-\mu}$$

where I is the photocurrent observed for the depth in question, corrected for the decrease with time as before mentioned, and I_a is the photocurrent observed in air taken at the beginning of the series, μ being the extinction coefficient for light of the character used per 1 metre length of water column traversed.[1])

Measurements made in this manner give immediate information of the relative transparency of the water layers at different depths investigated[2]). Where, on the other hand, values of transparency are required in definite units, comparable with those obtained by other workers using the same instrument, care should be taken that the light emitted from the projector has the same colour temperature and also that the divergence of the beam of light from the projector is approximately the same. The use of a colour filter in front of the lamp of not too low a transmission giving a light resembling daylight in its spectral composition in moderate depths, say a VG9, 1 mm. thick, might be suggested for such a purpose, should necessity for standardizing the transparency values arise.

Otherwise the same precautions advised for work with the submarine photometer described above should be observed also with the combined daylight-transparency meter[3]).

---

[1]) Immersed in a perfectly transparent liquid of the same refractive index as water the intensity of the lamp light reaching the cell should be increased from I_a in air to $1{\cdot}9 \times I$, partly owing to the contraction of the light beam increasing the intensity within a given cross section by the factor n^2, partly owing to the reduced intensity loss through reflection at two glass to water surfaces as compared to two glass to-air surfaces, the gain amounting to about 3% at each.

[2]) By means of a transparency meter of somewhat similar construction, investigations made in freshwater lakes in Wisconsin by Whitney have recently revealed a microstructure of the lake water characterized by very marked variations with depth in the transparency within layers only a few centimetres thick (*Science*, Febr. 26, Vol. 85, 1937, p. 224).

[3]) Together with a small pointer galvanometer from A. E. G. of Berlin the combined daylight and transparency meter was put to practical tests by the biologists onboard the "Skagerak" during a cruise in the Faroe waters in July 1937 and was found to give excellent results, as it also did in a moderate swell in the open Atlantic ocean.

References.

Atkins, W. R. G., 1932. Solar Radiation and its Transmission through Air and Water. Journ. du Conseil, VII, p. 171.

Atkins, W. R. G., Ball, N. G., and Poole, H. H., 1937. The Photo-Electric Measurement of the Diurnal Variations in Daylight in Temperate and Tropical Regions. Proc. Roy. Soc. London, A **160**, 526.

Atkins, W. R. G. and Poole, H. H., 1933. The Photo-Electric Measurement of the Penetration of Light of various Wave-Lenghts into the Sea and the physiological Bearing of the Results. Phil. Trans. Roy. Soc. London, B **222**, 129.

Atkins, W. R. G. and Poole, H. H., 1933. The Use of Cuprous Oxide and other Rectifier Photo Cells in Submarine Photometry. Journ. Mar. Biol. Assoc., **19**, 67.

Clarke, G. L., 1933. Observations on the Penetration of Daylight into mid Atlantic and Coastal Waters. Biol. Bull., **65**, 317.

Clarke, G. L., 1936. Light Penetration in the Western North Atlantic and its Application to Biological Problems. Rapp. et Proc.-Verb., CI, 2me partie, No. 3.

Clarke, G. L., and Oster, R. H., 1934. The Penetration of the Blue and Red Components of Daylight into Atlantic Coastal Waters and its Relation to Phyto-Plankton Metabolism. Biol. Bull., **67**, 59.

Kalle, K., 1938. Zum Problem der Meerwasserfarbe. Ann. d. Hydr. usw., **66**, 1.

Lange, B., 1936. Die Photoelemente und ihre Anwendung. 1 & 2, Barth, Leipzig, 1936.

Pettersson, H., 1934. A Transparency-Meter for Sea-Water. Medd. Göteborgs Högskolas Oceanogr. Inst., 7.

Pettersson, H., 1936. The Transparency of Sea-Water. Rapp. et Proc.-Verb., CI, 2me partie, No. 6.

Pettersson, H. and Landberg, S., 1934. Submarine Daylight. Medd. Göteborgs Högskolas Oceanogr. Inst., 6.

Pettersson, H. and Poole, H. H., 1937. Measurements of Submarine Daylight. Medd. Göteborgs Högskolas Oceanogr. Inst., 13.

Poole, H. H., 1936. The Photo-Electric Measurements of Submarine Illumination in Offshore Waters. Rapp. et Proc.-Verb., CI, 2me partie, No. 2.

Poole, H. H. and Atkins, W. R. G., 1933. Experiments on the Suitability of some Rectifier Cells for Submarine Photometry. Scient. Proc. R. Dub. Soc., **29**, 537.

Poole, H. H. and Atkins, W. R. G., 1934. The Use of a Selenium Rectifier Photo-Electric Cell for Submarine Photometry. Journ. Mar. Biol. Assoc., **19**, 727.

Poole, H. H. and Atkins, W. R. G., 1934. The Measurement of the Current Generated by Rectifier Photo-Cells. Scient. Proc. R. Dub. Soc., **21**, 133.

Poole, H. H and Atkins, W. R. G., 1936. The Standardization of Photo-Electric Cells for the Measurement of Energy. Scient. Proc. R. Dub. Soc., **21**, 363.

Poole, H. H. and Atkins, W. R. G., 1937. The Penetration into the Sea of various Wave Lengths as measured by Emission of Rectifier Cells. Proc. Roy. Soc. London, B. **123**, 151.

Takenoutt, Y., 1936. Solar Radiation in Lake Waters. Bull. Jap. Soc. Fish., **5**, 149.

Utterback, C. L., 1933. Submarine Illumination. Proc. Vth Pacific Scient. Congress, Vol. 3, 2153.

Utterback, C. L., 1936. Spectral Bands of Submarine Solar Radiation in the North Pacific and Adjacent Inshore Waters. Rapp. et Proc.-Verb., CI, 2me partie, No. 4.

(A complete list of publications will be printed with Dr. Ångström's paper mentioned on page 40.).

A Simplified Procedure for Colorimetric Analyses of Sea Water.

By

John P. Tully and Neal M. Carter,
Pacific Biological Station, Nanaimo, B. C.

MOST colorimetric analyses used in oceanographical studies are for the determination of the dissolved nutrient salts found in the sea. Since these substances are present in very low concentrations and there are many microscopic forms of life utilizing them, their concentration is in dynamic balance and changes very rapidly after the sample has been removed from its environment. For example, it has been observed that the concentration of the dissolved phosphates or silicates in a sample which has been kept for 3 hours may vary by as much as 50 per cent. of the value obtained on a fresh sample. If the samples are kept at room temperature (15°C.), the concentration of these constituents has been observed to fall rapidly to a minimum in about 6 hours, after which a maximum is slowly reached in about 36 hours. It is of importance that the samples be kept as nearly as possible at their temperature *in situ*, and that the analyses should be commenced within 20 minutes of their collection. The temperature difference between standards and samples should be as small as practicable at the time of analysis.

In order to complete colorimetric analyses as soon as possible after the samples had been taken, a special apparatus and technique were developed which considerably expedited the necessary procedures, and could be easily used at sea.

The apparatus and procedure described were originally designed for the standard analyses of dissolved phosphates by Atkins's (1923) modification of the cœruleomolybdic method of Denigès, silicates by the method of Dienert and Wandenbulcke (1923) employing the picric acid standards of King and Lucas (1928), and the nitrites by Germuth's (1929) modification of the Griess-Ilosvay method.

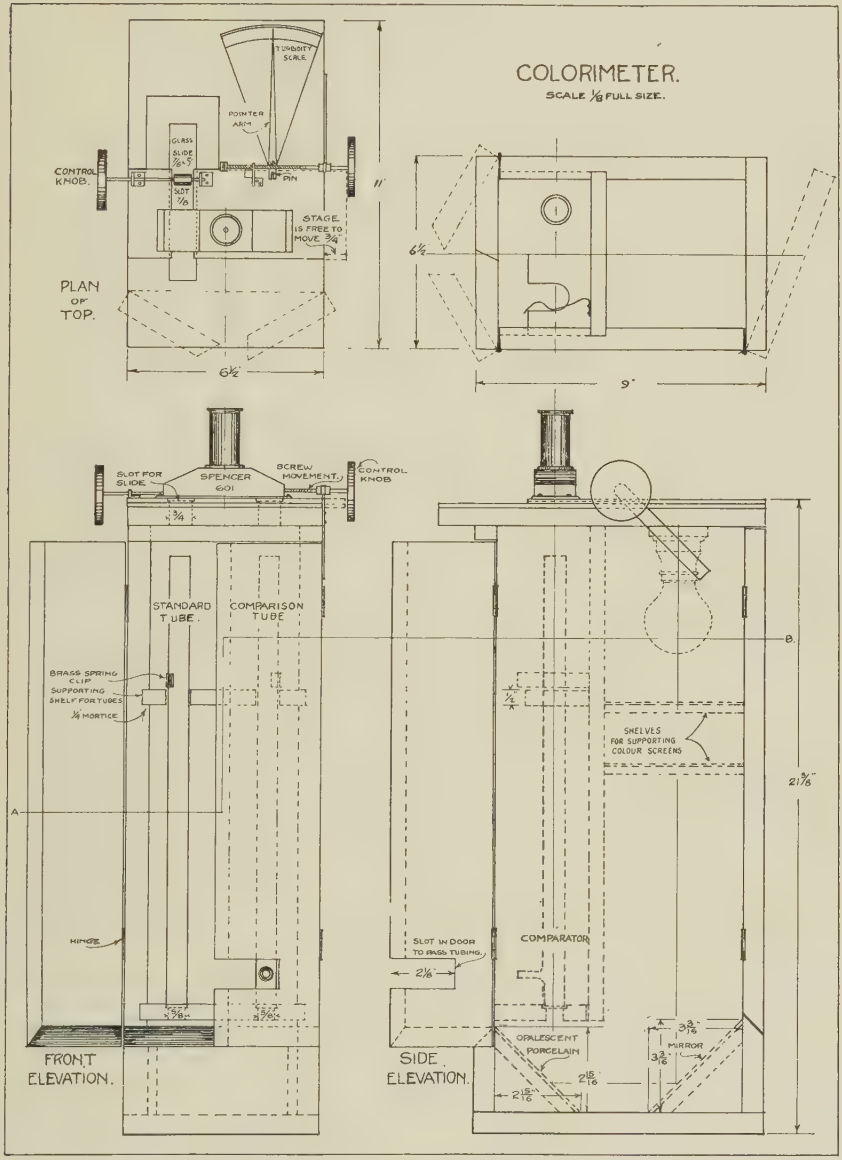


Figure 1. Construction of colorimeter.

Apparatus.

A colorimeter (Fig. 1) was constructed especially for oceanographical investigations where the analyses were to be made at sea, and was found to satisfy most of the requirements. An incandescent lamp was employed as a source of light, the rays from which were reflected vertically upward through the comparison tubes and were converged into the two halves of one field by means of the eyepiece of an ordinary Duboscq colorimeter. Provision was made for the insertion of colour screens in the path of the light and the instrument was suitably cased.

Some further modifications, such as compensating devices for turbidity and natural colour of the water, were found necessary in certain investigations. These accessories, however, do not appreciably alter the design of the instrument and they may be omitted from the construction.

To facilitate the procedure, tall ungraduated comparison tubes (38 cm.) fitted with a glass outlet-arm placed about 2·5 cm. from the bottom were obtained (Fig. 1). By fastening a short piece of rubber tubing, fitted with a pinch-cock, to the outlet arm, the level of the liquid in the tube may be lowered without removing it from the colorimeter. A set of tall, matched, 100-ml. Nessler tubes, made of the same glass as the comparison tubes, served as standard tubes.

Measurement of Concentration.

Beer's law, upon which colorimetric chemical analyses are based, states that the quantity of light absorbed in passing through a coloured medium is in direct proportion to the concentration of the coloured substance; hence in a simple coloured solution such as that of a dye, irrespective of the radii of the tubes, the heights of the columns of liquid in two colorimetrically matched tubes are in inverse proportion to the concentration of the coloured substance in those tubes. There are, however, two factors that interfere with the simplicity of the above proportionality when considering colours developed by the addition of chemical reagents:

(a) The colour intensity developed by the action of the reagents on the specific substance, under investigation in the solution, may not be directly proportional to the concentration of that substance. This has been demonstrated in the case of the analyses used for the detection of dissolved nitrates (Riddell 1936), and phosphates (Harvey 1929) in sea water, but is not so evident in the analyses for dissolved nitrites and silicates.

(b) The molecular extinction coefficient of the coloured solution may vary with the concentration of the solution, causing deviations from Beer's law.

Considerable research is necessary to distinguish the above two factors in their effect on colorimetric measurements. Temperature, salt errors, blank determinations, and interfering chemical substances also

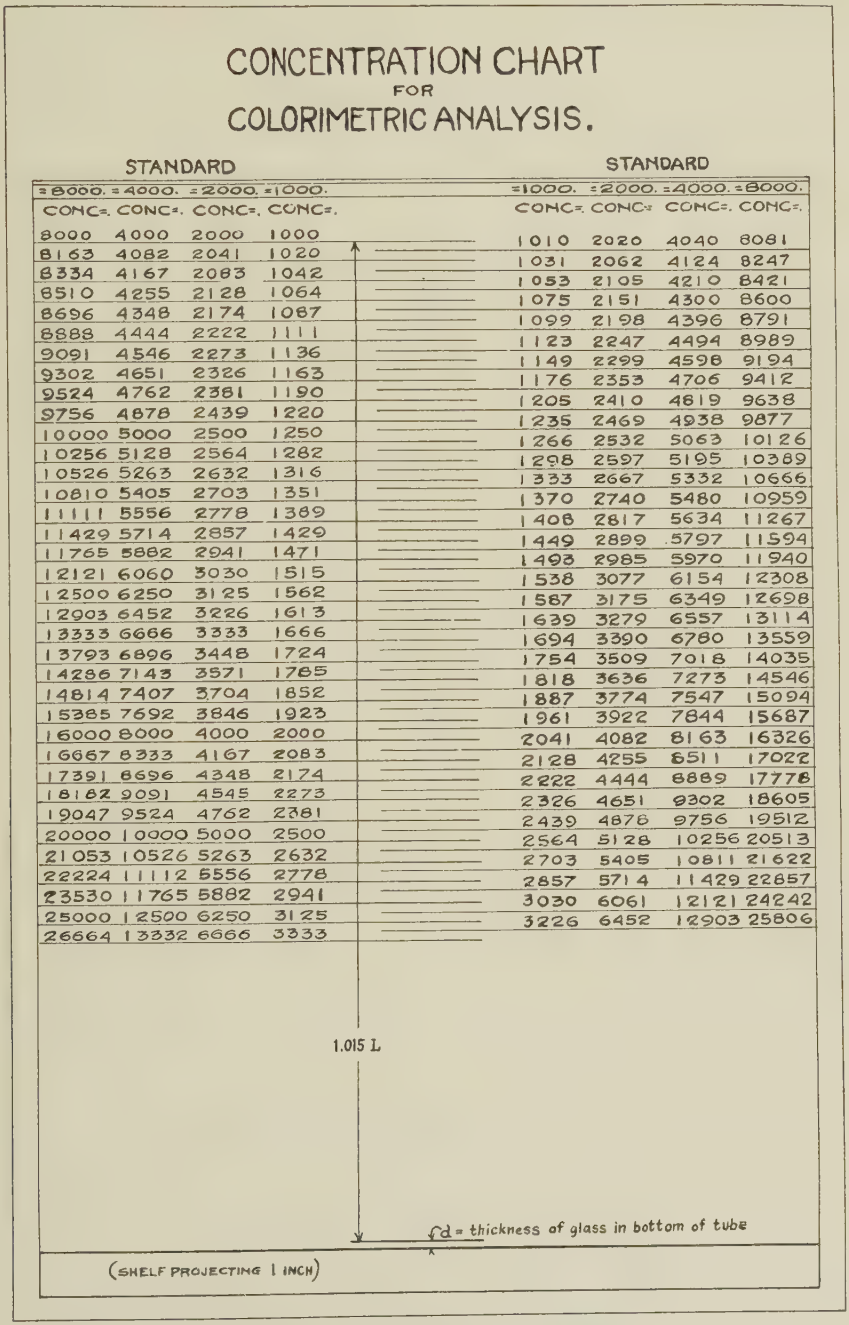


Figure 2. Chart for reading concentration from height of column of solution remaining in comparison tube after colorimetric analysis.

play an important role in individual determinations. This *technique* of concentration measurement has been developed on the assumption that ideal coloured solutions were being considered. Certain corrections are mentioned under the methods of analysis and a more complete discussion of the corrections that must be applied to the results after the analyses have been performed will be found in other publications (Robinson and Wirth 1935; Thompson and Houlton 1933; Riddell 1936).

The general colorimetric procedure adopted was to prepare one or more standard solutions in the 100-ml. Nessler tubes, and a series of water samples in the comparison tubes. After the necessary reagents were added and the development of colour was complete, the appropriate standard and each of the samples in turn were placed in the colorimeter and the level of the liquid in the comparison (sample) tube was lowered by means of the pinch-cock on the outlet arm until the colour intensities in the two were matched.

It was desired to obtain the concentration directly from the height of the column of liquid remaining in the comparison tube by measurement on a scale. However, two variations had to be considered. First, the volumes of reagents added to the tubes were 1·0, 1·5 and 2·0 ml. in the phosphate, silicate and nitrite tests respectively; second, in the silicate test an artificial standard was used that did not require the addition of reagents. In order that a single scale might be employed, all heights were referred to the uniform height of the 100-ml. graduation mark on the Nessler standard tubes. From theoretical considerations, it may be shown that the expression

$$C = C_s \times \frac{H + b}{H} \times \frac{L}{h} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

takes into account the above two variations, where

C = concentration of substance in the comparison tube,
C_s = concentration of substance in the standard tube,
H = height to which comparison tube was filled with the water sample,
b = additional height occupied by the reagents added to comparison tube
h = height of liquid remaining in the comparison tube after matching,
L = height of the 100-ml. graduation on the Nessler standard tubes.

Simplified formula. If the comparison tubes were filled to approximately the same height as the 100-ml. graduation on the standard tubes (i.e. $H = L$), the adoption of an approximate value of 1·5 ml. for the volume of reagents added causes b to become equal to 0·015 H. Moreover, since b is so small compared with H, an approximation to within ± 5 ml. of 100 ml. in filling the comparison tubes to height H (= L) causes insignificant changes in the value of the factor $\frac{H + b}{H}$ in the above equation. These two approximations allow the equation to be simplified to

$$C = C_s \times \frac{1{\cdot}015\ L}{h} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

and the tolerance of ± 5 ml. in filling the comparison tubes with the sea-water samples at sea is of considerable advantage. In making up standards by dilution of a known pipetted volume of concentrated standard with distilled water in the Nessler tubes, the same tolerance is admissible in filling to the graduation mark since the height of the solution in this tube does not appear in either formula. The most unfavourable combination of approximated values indicated causes an error of less than 0·6 per cent. between C as calculated by formulae (1) and (2). When using standard solutions already made up to working concentration, as in the silicate test, it is essential to fill the standard tubes to exactly the height L represented by the 100-ml. graduation.

Concentration scale. An upright scale (Fig. 2), permitting the direct reading of the unknown concentration C from the column height h of the matched sample, was evaluated from formula 2. This scale was of height 1·015 L, uniformly subdivided into hundredths.

By substituting $C_s = 1{,}000$ and giving h the successive values of 1·015 L (1·00, 0·99, 0·98, ...) in formula 2, the values of C for each division (commencing at the top) could be copied from a table of reciprocals. Multiples of the above values, corresponding to frequently employed multiples of a standard concentration $C_s = 1{,}000$, were inserted alongside, arranged in columns. Only the upper half or two-thirds of the scale need be graduated, since colorimetric practice demands the use of a more concentrated standard when C exceeds $2C_s$. The scale was mounted vertically with its lower limit a distance d above a narrow wooden shelf, where d was the thickness of the glass bottom in the comparison tubes.

After the colorimetric matching was completed, the comparison tube was placed upright on the shelf and the concentration C read opposite the meniscus in the column under the appropriate concentration of standard. Interpolation is not linear, but is seldom necessary, in view of the limitations in the accuracy of colour intensity comparison. The concentration scale (Figure 2) derived from equation 2 makes no provision for the random concentrations of the standard found when using standardized sea water (Tully and Carter 1937). When employing such standards in analysing a series of samples in comparison tubes, it was customary to record the heights of the residual solution in these tubes as read under the "standard 1,000" column. These values were later proportionally adjusted to the actual concentration of the sea-water standard.

Determination of Turbidity.

Experiments with the colorimeter showed that, if the distance between the axes of the tubes was made slightly greater or less than the distance between the axes of the Duboscq eyepiece objectives, the optical effect of turbidity could be simulated in one of the tubes.

Over the small area of cross-section of a tube the meniscus is concave and tends to focus the light. Therefore, if the centre of one of the eyepiece objectives is directly over the centre of one of the tubes, this objective will be receiving a maximum intensity of light while the centre of the other objective, not directly over the centre of the other tube, will receive less light.

Suspended solids have the effect of interfering with the light transmitted by the solution, and by moving the eyepiece laterally, varying proportions of light can be accepted from either tube; hence the interference due to turbidity in the comparison tube may be compensated in the standard tube by suitable movement of the eyepiece.

Apparatus. In the construction of the colorimeter (Figure 1) the upper part carrying the Duboscq eyepiece was mounted on a sliding stage so that it could be moved horizontally in a direction parallel to a line joining the centres of the two tubes. For convenience, a screw movement was fitted to this stage and a pointer arm attached to indicate the extent of the adjustment. A scale was placed under this pointer and fastened only by the screw that held the pointer arm; thus the scale could be adjusted around the same centre as the pointer. This was empirically graduated as a turbidity scale in terms of milligrams of suspended kaolin per litre, and it was found that the range of adjustment was sufficient to compensate for any turbidity commonly found in the sea water near river deltas.

Procedure. In practice, two tubes of distilled water were placed in the colorimeter and the stage was set in such a position that the two fields exactly matched. After the scale had been set so that the zero was directly under the pointer, a sample of sea water was substituted for the tube of distilled water in the comparison position and the stage moved until an exact match was obtained. The scale reading under the pointer then indicated the amount of suspended material in the sea water.

This method was found to be very rapid and reasonably accurate; readings could be duplicated within 2 per cent.

Determination of Natural Colour.

A compensation or correction for a natural yellowish colour observed in some sea-water samples was frequently necessary before the yellow colour developed in the test for dissolved silicates could be determined accurately; a record of the intensity of the natural colour was also desirable in many cases.

Apparatus. In the colorimeter (Fig. 1) the compensation for natural colour was accomplished by placing a coloured glass slide between the eyepiece objective and the standard tube. This could be moved horizontally in a direction normal to the movement of the stage and did not interfere with the adjustment of the latter. To keep the under side free from all contacts, the slide was placed in a slot on two narrow shoulders and its motion was controlled by a rubber roller

with a friction contact on the upper surface. It was coloured by applying a film of gelatine containing picric acid to the under side in such a way that the intensity varied from zero to that developed in a solution containing 0·02 mg.-atoms of silicate silicon per litre. In order to counterbalance the effect of the glass in the coated slide, a piece of glass identical with the slide, but uncoated, was placed between the other eyepiece objective and the comparison tube.

A scale mounted under the leading edge of the coated slide was empirically graduated in terms of the colour (apparently imparted to a tube of distilled water placed in the field) which would be produced by treating different concentrations of dissolved silicate in that tube with the proper reagents. A parallel scale graduated in equal divisions also proved useful.

Procedure. A tube of distilled water was placed in the colorimeter in the position usually occupied by the standard, and the sample of sea water in the comparison position. With the slide set at zero colour the fields were first compensated for turbidity. The slide was then moved until the colour of the fields apparently matched, and the reading on the natural colour scale was noted. Further analysis of the sample for its content of dissolved silicates then proceeded without the use of the slide, the observed correction being applied arithmetically to the analytical results.

General Procedure for Phosphate, Silicate, and Nitrite Determinations.

After the determination of the turbidity and natural colour of each sample, the necessary reagents for the next analysis (usually phosphate) were added. If the turbidities and natural yellow colours of the samples were negligible, the phosphate concentrations were determined directly. If the turbidity or the natural colour (or both) was appreciable in any of the samples, former readings for each sample were again set on the respective colorimeter scales before proceeding with the phosphate determination. During the matching, as the level of the liquid in the comparison tube was lowered, a proportional diminution of the turbidity and/or colour artificially imparted to the standard was effected by altering the setting of the eyepiece and glass slide. Each time a change in setting was made, the colour was again matched until by a series of approximations the true colour match was obtained.

On occasional instances when a turbid or yellowish sea water was of necessity employed in preparing a standard (Tully and Carter 1937), the proportional turbidity and colour compensations were made in the opposite sense; that is, to the sample instead of to the standard.

After some practice, readings with the colorimeter could be made very quickly and were duplicable to within 1 per cent. under working conditions at sea.

Summary.

A simple colorimeter is described, utilizing an electric lamp as a source of light, a Duboscq eyepiece, and long comparison tubes. The instrument can be used to determine natural colour and turbidity as well as for the routine colorimetric analyses. A simple field procedure in which the concentration of the sought substance is determined from a scale is discussed.

References.

Atkins, W. R. G. The Phosphate Content of Waters. Journ. Mar. Biol. Assoc., **13,** 1, 143—147, 1923.

Dienert, F. and F. Wandenbulcke. Determination of Silica in Waters. Bull. Soc. Chem. **33,** 1131—1140, 1923.

Germuth, F. G. Dimethyl-alpha-naphthylamine for the Determination of Nitrite Ion. Journ. Ind. Eng. Chem. (Anal.), **1,** 28—29, 1929.

Harvey, H. W. Methods of Estimating Phosphates and Nitrates in Sea Water. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., **53,** 1929.

King, E. J. and C. C. Lucas. The Use of Picric Acid as an Artificial Standard in the Colorimetric Estimation of Silica. Journ. Amer. Chem. Soc., **50,** 2395—2397, 1928.

Riddell, W. A. The Reduced Strychnine Method for Determining Nitrates in Sea Water. Journ. Biol. Bd. Can., **2,** 1—11, 1936.

Robinson, R. J. and H. E. Wirth. Photometric Investigation of Ceruleomolybdate Determination of Phosphates in Water. Journ. Ind. Eng. Chem. (Anal.), **7,** 147, 1935.

Thompson, T. G. and H. G. Houlton. Determination of Silicon in Sea Water. Journ. Ind. Eng. Chem. (Anal.), **5,** 417—418, 1933.

Tully, J. P. and N. M. Carter. The Standardization of Sea-Water Standards in Colorimetric Analyses of Sea Water. (Unpublished).

The Expression of Sea-Water Analyses as Milligram-Atoms per Litre.

By

John P. Tully,
Pacific Biological Station, Nanaimo, B. C.

IT was recommended at the Fifth Pacific Science Congress, 1933, that: "The constituents of sea water be expressed as milligram-atoms per kilogram of sea water, and that the general chemical nature of the sea water as a function of its physical properties be expressed as chlorinity". (Carter, Moberg, Skogsberg, and Thompson 1934.)

This was further modified at the meeting of the International Association of Physical Oceanography in Edinburgh, 1936, where it was resolved that the concentration of the dissolved gases and the minor inorganic constituents should be reported as milligram-atoms per litre at 20°C.

Since it is impossible to perform the analyses on a weight basis, it is most convenient to express the results as milligram-atoms per litre. In addition, it is then possible to make direct comparison of the concentration of the various constituents in relation to their biological significance.

Adoption of the milligram-atom system was in colorimetric sea-water analyses facilitated by preparing standard solutions of the appropriate concentrations and using the factors given in Table 1 to convert the results of former analyses for the dissolved substances containing oxygen, phosphorus, silicon, nitrogen, and carbon. The weight per unit volume of any of these elements in one of the forms given, multiplied by the factor indicated, will be converted to weight-atoms per volume, in the same units of weight and volume as the original data. Thus concentrations expressed in milligrams per litre, when multiplied by the appropriate factor, are converted into milligram-atoms per litre.

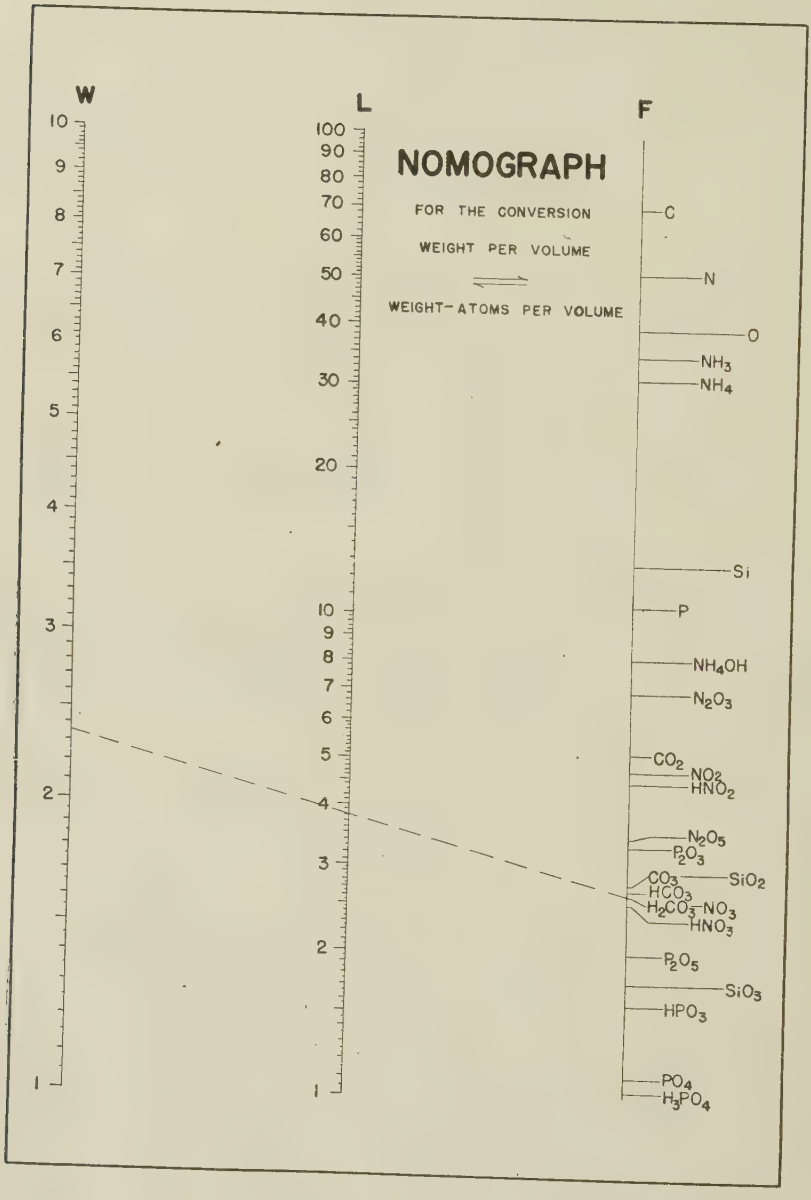


Figure 1. Nomograph for the conversion of concentration units to the milligram-atom system.

Table 1.

Factors for converting Concentrations of various Constituents of Sea Water from Weight per Volume to Weight-Atoms per same Volume.

Element in italics determined as	Factor for conversion from weight per volume to weight-atoms per same volume
O or O_2	0·06250
P	0·03223
P_2O_3	0·01818
P_2O_5	0·01408
HPO_3	0·01250
H_3PO_4	0·01020
$(PO_4)^-$	0·01052
N or N_2	0·07139
N_2O_3	0·02631
N_2O_5	0·01852
HNO_2	0·02127
HNO_3	0·01587
$(NO_2)^-$	0·02174
$(NO_3)^-$	0·01613
NH_3	0·05871
$(NH_4)^+$	0·05543
NH_4OH	0·02853
Si	0·03564
SiO_2	0·01665
$(SiO_3)^=$	0·01315
C	0·08333
CO_2	0·02273
$(HCO_3)^-$	0·01639
H_2CO_3	0·01612
$(CO_3)^=$	0·01667

The nomograph shown in Figure 1 was constructed with the aid of Table 1 to facilitate the above conversion. If a straight-edge is placed across the scales in such a manner that it cuts the "weight" scale (W) at the point representing the significant digits of a value expressed in weight units per volume, and the "factor" scale (F) at the form in which a given element was determined, the intersection of the straight-edge with the "L" scale indicates the significant digits of the value in terms of weight-atoms per volume. The situation of the decimal point is readily determined by observing the rule, that for all the constituents shown on the nomograph, the decimal point in the value of any concentration expressed as weight-atoms per litre is two places further to the left than in the value expressed in the same weight unit per litre, or five places further to the left than in the value expressed in the same weight unit per cubic metre.

In the example shown, 2·35 milligrams per litre of nitrate nitrogen were determined. The broken line indicates that this is equivalent to 0·0380 milligram-atoms per litre of nitrogen as nitrate. Had the

concentration been 2·35 milligrams per cubic metre, then the equivalent would have been 0·0000380 milligram-atoms per litre.

As most analyses are made within the limits of room temperature (12° to 25°C.) the conversion of the concentration of the substances listed from the temperature of observation to 20°C. does not introduce a change that is greater than the limit of error of routine analyses for these substances. For this reason it is not necessary to consider the change of volume within the range of room temperature, except in special cases.

Summary.

A table and nomograph are given for converting the concentrations of Oxygen, Phosphorus, Nitrogen, Silicon, and Carbon, as usually determined in sea-water analyses in metric units, to the milligram-atom system as recommended by the 1936 meeting of the International Association of Physical Oceanography.

Reference.

Carter, N. M., E. G. Mœberg, T. Skogsberg and T. G. Thompson. The Reporting of Data in Oceanographical Chemistry. Proc. Fifth Pac. Sci. Cong., III, 2123—2127, 1934.

Variation in the Mean Vertebral Count of Herring *(Clupea pallasii)* with Water Temperature.

By

Albert L. Tester,
Pacific Biological Station, Nanaimo, B. C.

CONSIDERABLE evidence has appeared in the literature in recent years to indicate that variation in the number of vertebrae and certain other meristic characters in fishes is caused in part at least by variation in environmental conditions, notably water temperature. In the herring, where the vertebral count has been used extensively to segregate races, local forms and local populations, this conclusion has been reached recently by several investigators.

In the Atlantic herring, Runnstrøm (1933) points out that variation in the mean vertebral count of the 0-group of spring spawners along the coast of Norway in 1931 corresponds with variation in March water temperatures at a depth of 50 m. Relatively low mean counts and high temperatures are present in the vicinity of Stadt, and the mean counts become progressively higher and the temperatures progressively lower towards both the north and south of this central area. Runnstrøm concludes: "Es scheint deshalb sehr wahrscheinlich, dass die Variabilität von Vert. S. bei dem norwegischen Hering durch die verschiedenen hydrographischen Verhältnisse an den Laichplätzen hervorgerufen wird."

In the Pacific herring, Rounsefell and Dahlgren (1932) show that the mean vertebral count of successive year-classes at Prince William Sound, Alaska, is inversely correlated with mean air temperature during the combined months of March, April, May, and June, the period during which the herring spawn and the vertebral columns develop in Alaska waters ($r = -0{\cdot}85$; $P < 0{\cdot}01$). They also show that the mean air temperature is directly correlated with mean surface water temperature during the same four months in one locality ($r = 0{\cdot}93$; $P < 0{\cdot}01$). They state: "The differences in the vertebral count found between different year classes are probably due entirely to environment." Tester (1937) arrives at a similar conclusion for

herring of northern British Columbia, obtaining a fairly significant negative correlation between the mean count of a year-class and mean air temperature during the spring months at Jap Inlet ($r = -0{\cdot}83$; $P = 0{\cdot}02$). A similar significant relationship is not encountered in the Barkley Sound and Saltspring Island populations in southern British Columbia, but here it is found that mean spring air temperatures are not necessarily correlated with mean spring water temperatures on the spawning grounds. Other factors detracting from a close relationship are also discussed.

With the accumulation of additional vertebral data and with access to water temperature series it is now possible to investigate this problem in southern British Columbia with more precision.

In Table 1 are given the mean vertebral counts of ten successive year-classes of herring from Barkley Sound on the west coast of Vancouver Island. The counts were made on samples of the commercial catch taken from 1930—31 to 1936—37 inclusive. In most of the year-classes, fish of several ages (II to VII) are represented and the numbers in the age-groups are roughly in the same proportion among the various classes. However, the mean count of the 1926 year-class is probably slightly high and that of the 1935 year-class slightly low in relation to the others, as the former consists entirely of old and the latter entirely of young fish. These errors, induced by the tendency of the mean count of a year-class to increase with age (Tester 1937) are sufficiently small to be neglected in the computations which follow.

Table 1.

Mean Vertebral Counts of Year-Classes of Herring taken in Barkley Sound from 1929—30 to 1936—37.

Year-class	Mean ($\bar{x}$)	Number (n)	$S(x-\bar{x})^2$
1926	51·649	37	16·432
1927	51·757	206	79·864
1928	51·857	209	85·694
1929	51·903	288	115·278
1930	51·838	580	216·766
1931	51·757	822	349·338
1932	51·898	517	197·567
1933	51·922	663	245·922
1934	51·765	469	190·200
1935	51·868	38	14·342

In Table 2 are given mean monthly water temperatures (at one fathom depth) based on daily observations made at William Head, some 80 nautical miles to the south-east of Barkley Sound. This is the nearest point to Barkley Sound for which regular temperatures are available over the period 1926 to 1935. Comparison of monthly averages at William Head with those at Amphitrite Light at the entrance to Barkley Sound during 1935, 1936, and 1937 shows a greater range of seasonal variation in the latter, but fairly close correspondance

in annual deviations from the average temperature during the early months of the year. This is illustrated by the following averages of the temperatures during February, March, and April:

	1935	1936	1937
Amphitrite Light	8·0	7·6	7·8
William Head	7·6	7·2	7·5

Although the averages for William Head are lower in each year, fluctuations from year to year are in the same direction and of similar magnitude in the two places. It is considered, therefore, that the William Head data reflect fluctuations in general spring temperature conditions at Amphitrite Light and Barkley Sound. Thanks are tendered to Mr. I. E. Cornwall and Capt. G. Hansen of the Quarantine Station, Victoria, for the William Head data, and to Mr. C. Fletcher, Lightkeeper, for the Amphitrite Light data. Mr. J. P. Tully, Pacific Biological Station, gave access to these records and contributed to their interpretation.

Table 2.

Mean Monthly Water Temperatures taken at William Head (Deg. C).

Year	Jan.	Feb.	Mar.	Apr.	May
1926	7·9	8·0	8·6	9·2	10·1
1927	7·6	7·4	7·8	8·1	8·9
1928	6·9	7·3	7·9	8·6	9·8
1929	7·2	6·4	7·1	7·8	9·1
1930	6·6	6·6	7·2	8·3	9·3
1931	7·9	7·9	8·2	8·9	9·9
1932	7·1	6·8	7·3	8·2	9·3
1933	7·1	6·8	7·1	8·0	9·0
1934	7·9	8·0	8·4	9·4	10·0
1935	7·3	7·3	7·5	7·9	9·4

Before discussing the relationship between mean vertebral count and water temperature it is desirable to consider the location of the spawning grounds and the time of spawning of herring in Barkley Sound. Spawning takes place for the most part on beaches and rocky shores in the intertidal zone, and the eggs adhere both to each other and to the aquatic vegetation on the grounds. Because of this, water temperatures at a depth of one fathom rather than those at a greater depth are used in this study. In Barkley Sound, spawning takes place on both exposed shores and within many of the inlets as far inland as the entrance to the Alberni Canal. Spawning reports which have been collected in collaboration with the Dominion Department of Fisheries over a period of 8 years (1930 to 1937) show that the average percentage of recorded spawnings occurring in each month is distributed as follows: Jan., 1·9; Feb., 30·2; Mar., 61·3; Apr., 5·7; May, 0·9. Over the 8 years 50 % of the spawnings have been recorded between

February 21st and March 17th, a period of 25 days. Laboratory experiments by the author have shown that the eggs of *C. pallasii* hatch in about 14 days at 8·0°C. and in about 18 days at 7·0°C. The time at which the vertebra number is fixed has not been determined, but the vertebral column appears to be completely ossified in about three months after hatching when the young fish average about 35 mm. in length.

Correlation coefficients between mean vertebral counts of the year-classes and mean water temperatures were calculated according to the formula of Fisher (1932, p. 116) and their significance was appraised from probability values derived from Fisher's Table VA.

Using average temperature data for the combined months of both February and March, and February, March and April, a significant correlation of —0·87 ($P<0·01$) was obtained. This shows that in Barkley Sound the mean vertebral count of a year-class is related to the water temperatures during the months of spawning and early development.

In an attempt to determine more accurately the time at which the vertebral number is fixed, correlation coefficients have been calculated between the vertebral data and the mean temperatures of each of the months in which spawning has been reported. The results are as follows:

Month	*r*	P
Jan.	—0·74	0·01—0·02
Feb.	—0·82	<0·01
Mar.	—0·89	<0·01
Apr.	—0·75	0·01—0·02
May	—0·63	0·05

The value of the coefficient increases gradually from —0·74 with the January data to a peak of —0·89 with the March data and then decreases somewhat more rapidly to —0·63 with the May data. Statistically, the coefficient is highly significant for February and March, significant for January and April and on the borderline of significance for May.

To interpret the reason for the gradual change in the value and significance of the coefficient it must be kept in mind that each year-class on which the counts were made consists, presumably, of a mixture of fish most of which were spawned and underwent their early development in February and March. The two highest coefficients are thus obtained with temperature data during the two months of most intensive spawning. The values of the coefficients for all months relative to that of March are higher than might be expected from a consideration of the time distribution of the reported spawnings, but this is due to the fact that deviations from average conditions which will induce vertebral variation are similar to a large extent during each of the first five months of the year. Considering the facts (1) that the highest correlation is obtained with the March data, and the

second highest correlation with the February data, (2) that 61 % of the reported spawnings take place in March and 30 % take place in February, (3) that 50 % of the reported spawnings take place between February 21st and March 17th, and (4) that the larvae take from about two to three weeks to hatch at the prevailing temperatures, it seems reasonable to conclude that on the average the vertebra number of individual fish is already fixed within a short time after hatching — probably within a month and possibly within two weeks. In individual cases the time may be shorter or longer, for it probably varies with the time of spawning within a particular year and from year to year, and depends on the temperature of the water and its effect on the rate of development.

The data presented demonstrate that in Barkley Sound, southern British Columbia, the mean vertebral count of successive year-classes of herring varies inversely with the temperature of the water during the period of spawning and early development. This conclusion is in accord with that of Runnstrøm (1933) who had but one year's data at his disposal, of Rounsefell and Dahlgren (1932) who used air temperature as an index of water temperature, and of Tester (1937) who also used air temperature but who found a significant relationship only in northern British Columbia. It follows that significant differences between the mean counts of year-classes in the same locality, e.g., between the 1933 and 1934 classes in the present data, are largely if not entirely due to annual differences in environmental conditions during the period between fertilization of the egg and ossification of the vertebral column. The results further indicate that the vertebra number of individual fish is already fixed within a short time after hatching.

References.

Rounsefell, G. A. and E. H. Dahlgren. Fluctuations in the supply of herring, *Clupea pallasii*, in Prince William Sound, Alaska. U. S. Bureau of Fisheries, Vol. XLVII, Bull. No. 9, 1932.

Runnstrøm, Sven. Über die Rassenverhältnisse bei dem norwegischen Frühjahrshering mit besonderer Berücksichtigung der Konstanz der Rassenmerkmale. Journ. du Conseil, Vol. VIII, No. 2, 1933.

Tester, Albert L. Populations of herring *(Clupea pallasii)* in the coastal waters of British Columbia. Journal of the Biological Board of Canada, Vol. 3, No. 2, 1937.

Rates of Fishing and Natural Mortality from the Data of Marking Experiments.

By

Michael Graham,

Fisheries Laboratory, Lowestoft.

Introduction.

IN estimating the toll fishermen take of the stock of fish, it has been usual to mark a certain number of fish and find the percentage that are returned within a year. Three papers, if not more, contain remarks aiming at an improvement on this way of treating the data, namely those of Graham (1924), Thompson and Herrington (1930) and Wollaston (1933). Thompson and Herrington dealt with the matter at length, their data being particularly well arranged for the purpose. The principal aim of the present notes is to introduce a new method of treating the data, which method is thought to be theoretically rather more clear than the method used by Thompson and Herrington, but otherwise owes much to those workers. At the same time the whole subject needs rather more detailed consideration than it appears to have had in the past. The conclusions that the present author has been able to reach seem important to those who are contemplating making further marking experiments, because there are ways of arranging the work so that correct conclusions can be drawn. It is quite easy, through lack of attention to the methods which it is hoped to use in working up the data, to accumulate a large volume of data, which are less useful than they might have been.

The estimate of the proportion of a stock of fish that is caught is used in two problems. First, the one which is in some cases within our reach, — to advise whether a given stock is overfished or not. Second, to obtain a rough estimate of what is the "optimum catch". This is more difficult, only approachable in certain cases at present, and not likely to give any better estimates than those already made, for many years to come. In these problems we have used the "rate of fishing" defined in a particular sense, namely:—

1. The catch in a moment of time expressed as a percentage of the stock at that moment.

This is the definition used in Graham (1935), but it was not explicitly stated there. On the other hand, were a layman asked how he would measure the rate of fishing, he might well reply —

2. The catch in a year expressed as a percentage of the average stock in that year.

This, No. 2, is a very simple idea, whereas No. 1 involves the conception of instantaneity. Nevertheless, it will be shown that these two definitions have the same numerical value, under the assumption that is used in working overfishing problems, namely that the catch is as much and no more as will leave the stock unaltered. This kind of catch was called the yield in earlier papers. A good word would be "crop", which conveys the idea of an annual product, determined partly by nature, not merely by markets and human plans.

It is thought that a certain mental construction helps in understanding marking experiments and other work in connexion with overfishing. This structure is built up from studies of money and of growth and mortality, and its application to fishery science is recent and reluctant. It, therefore, seems worth while to illustrate the construction by imaginary cases, a procedure that has two advantages. The discussion is liberated from the idiosyncrasies of particular data, and we can consider such familiar things as money and rabbits. The problems all seem easier in terms of familiar things, instead of fish that are mainly invisible.

That it is worth while to use instantaneous rates in this problem will be admitted at once, when it is understood that this method gives a result independent of shedding of marks and other accidental losses, in certain common cases.

An opportunity may be taken to make belated acknowledgment of work by Baranov (1916), which has most undeservedly been ignored hitherto. He should have priority for much that has innocently been included as original in later papers on overfishing. The theoretical structure proposed in the present paper is, however, somewhat different from the system of Baranov and is thought to be more convenient.

Graphical Definitions.

This is supposed to be useful to those who have made some mathematical study. In Fig. 1 AB is an ordinate representing number of fish at exactly 3 years old, CD number at 4 years old, and FG number at an intermediate point, say, at 3½ years old. HFK is the tangent to the curve of survival at F. EC and LK are construction lines, parallel with, and equal to, BD. The "death-rate" between the ages of 3 and 4 years is:—

$$\frac{AE}{AB.\ t}$$

I should prefer to call this the "percentage-reduction".

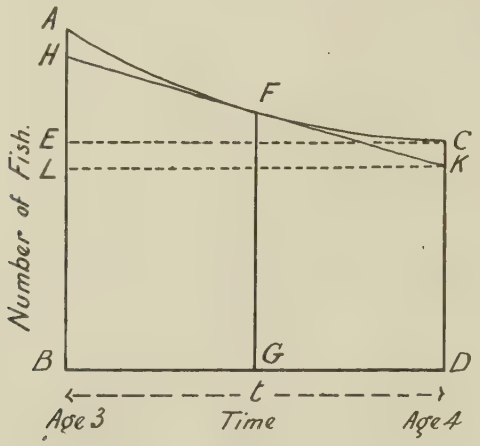


Fig. 1.

The instantaneous rate of mortality at the age of 3½ years is:—

$$\frac{HL}{FG.\,t}$$

which, in the notation of the calculus, is:—

$$\frac{1}{S} \cdot \frac{dS}{dt}$$

where S stands for the number in the stock. It has been assumed that the rate of mortality is constant between the ages of 3 and 4 years.

Continuous Simple Interest.

We consider a man, A, who puts 1000 kroner in the bank and determines to spend the interest as soon as it is paid, so as to keep his stock the same. If interest is allowed at 6 % per annum, and books are made up once a month, the bank will pay ½ % per month, and he will draw the sum of 5 kroner twelve times during a year. His yield will be 60 kroner, or 6 %, just the same as if the books were made up yearly. If the books are made up weekly, he would make 52 drawings of 1/52 of 6 %. If daily, there would be 365 drawings of 1/365 of 6 %. In fact, if the books were made up hourly, or even every minute, his yield would always be the same, 60 kroner, or 6 % of 1000. If the reader will now conceive of the processes of making up books and paying out as continuous, as it were money flowing in and leaking out simultaneously, he will readily believe that the effect will be the same. An instantaneous rate gives the same yield as a rate at simple interest, if the stock remains the same. That is, definitions Nos. 1 and 2 are equivalent.

Continuous Compound Interest.

If, however, the bank allows no interest, and A wishes to spend his money gradually, he may decide always to draw a fixed percentage of what he has left. In this way, A rightly thinks that his money will last a long time. Suppose he decides to draw at 1 % per week, or at the rate of 52 % per year. His weekly drawings would be 10, 9·9, 9·8, 9·7, ... and there would be 52 such drawings, all of them less than 10 kroner, except the first. It is clear that he would not receive 52 % of his *original* sum, for which there would have to be 52 drawings of 10 kroner. The total of his weekly drawings actually comes to about 407 kroner, 113 kroner short of what he would have taken if he had left his money until the end of the year and then drawn 52 % of it. If he decided to draw at the same rate, but monthly, he would draw one-twelfth of 52 %, namely, 4·33 % per month. His twelve drawings would be 43·3, 41·4, 39·6, 37·9, 36·3, 34·7, 33·2, 31·8, 30·4, 29·1, 27·8, 26·6, which amounts to 412 kroner, 5 kroner more than by drawing weekly. Quarterly drawings, at the same rate of 52 % per annum, would give 130, 113, 98, 86; total, 427. Looking now at the remainder of his stock we have that, if he drew:—

Annually,	the remainder would be		480	kroner
Half-yearly,	„	„	548	„
Quarterly,	„	„	573	„
Monthly,	„	„	588	„
Weekly,	„	„	593	„

It is to be observed that the difference between quarterly and yearly drawings is no less than 93 kroner, whereas the difference between drawing every month and every week, which is about a quarter of a month, is only 5 kroner. The series of figures shows signs of approaching a limit as the interval between drawings is reduced. What, then, would be the remainder if there was no interval between the drawings; if the money flowed away, as we have already put it? Had no one heard of this problem before, they might put the values so far obtained on squared paper and draw a curve showing the relation between the time interval and the remainder. From this graph they could then read off the value for an interval of nil. From such a graph, which has been drawn, the remainder seems to lie not far from 595, certainly between 590 and 600. This, then, would be the remainder at the end of a year, of a thing decreasing continually by a fixed proportion of itself. Put in that way, the problem may be familiar as "logarithmical", and the following is the standard solution:—

$$\begin{aligned} \log 1000 &= 6{\cdot}91 \quad \text{(Napier's original natural logarithms)} \\ &\underline{-\ 0{\cdot}52} \quad \text{(52 \% per annum)} \\ &\quad 6{\cdot}39 \quad \text{which is the logarithm of} \\ &\quad 596 \end{aligned}$$

A, therefore, would draw 404 kroner this way — much less than if

the interest had all been drawn at the end of the year. A familiar case of the converse is that of the Life Insurance Offices, who reckon to charge us a little more if we pay premiums monthly instead of yearly in advance.

Rate greater than Unity or than 100 %.

We may now imagine, just by way of further illustration, that A is less cautious. This time he will draw at 1 % per day, or 365 % per annum. He may well be astonished to find that he still has some money left at the end. He starts this second year with 596 kroner. To save working out all the daily book-keeping, we will use the calculation with logarithms to find his remainder approximately:—

$$\log 596 = 6{\cdot}39$$
$$-\ 3{\cdot}65$$
$$2{\cdot}74 \text{ which is the logarithm of } 15$$

So, even a rate of 365 % per annum did not completely exhaust his funds. It might be useful to add that tables of common logarithms can be used in these calculations, the rule being that Napier's logarithms are converted to common logarithms by multiplying by the factor 0·4343. It will have been noted that 365 % per annum is also written 3·65 per annum.

Simultaneous Rates.

It requires a far-flung fancy to put the case of a marking experiment into terms of money, but it is a useful exercise, because it leads to a better appreciation of how many processes go to make up the percentage of marks returned. B is a thief. He hears, indirectly, that the local bank pays out 50,000 kroner of cash every day. He wonders how much they keep at the counter. If there is a lot, it may be worth taking the risk of a violent hold-up. He thinks it likely that the bank will, roughly speaking, keep a fixed amount at the counter. If too much accumulates they will pass it to the strong room; if too little, they will bring some out. Is the sum worth a hold-up? What is the proportion of the money paid out to their stock? He conceives the plan of marking 1000 notes of 1 krone each and sending them to the bank by various messengers late one evening, so that they become fairly well spread among the bank's stock of currency. He marks the notes in pencil, spoiling some in doing so, but this was not noticed at once (mortality due to marking). He advertised that next day he would pay a premium on notes that carried these pencil marks. The problem is, what relation has the percentage of marked notes that he receives to the proportion which 50,000 bears to the stock of currency at the counter? Some of his pencil marks were rubbed off (shedding of marks); some were unnoticed, or the finders did not bother to collect the reward; some had gone to the strong-room and would not come back to the counter (natural mortality). A little thought will show that the

percentage he collects is neither an instantaneous rate, nor a simple interest rate, but is something like the amount A collected from his fund when it was decreasing at compound interest. During the day of collection, the marked notes became a smaller and smaller proportion of the bank's stock. Their number fell by being detected as spoilt, by being put in the strong-room, by the marks rubbing off, and by being paid out. Of these processes B was only watching one, the last. His return of marked notes is something very different from what he set out to discover, the relation of the turnover to the stock. It is not such a simple case as that of A, because A's stock was only falling by the rate that gave him his yield. In regard to marked fish, it is fortunate that the solution of the problem is a good deal simpler than its statement.

Stock and Crop.

C is a farmer with one large rabbit-warren in the middle of his 100-acre farm, and no other warren for miles around. He kills 1000 rabbits a year, but local officials, being zealous to send in a report that they are fulfilling a Government's policy, instigate a prosecution against him for keeping too many rabbits. He, however, asserts that he keeps the numbers down to 100, or 1 rabbit per acre. The chairman of the Bench of magistrates agrees that, if he can substantiate this estimate, they would hold that the number was not unreasonable. The police, however, argue that it is ridiculous to say that there are only 100 rabbits, when 1000 rabbits per year are killed. C defends himself thus:— Out of 100 rabbits, he reckoned 1 buck to every 4 does, so at the beginning of the year he has 80 does. After 3 months these would have had, say, 320 young, making 420 rabbits in all; but he killed 250 and he reckons the cats and weasels took 70, so that there were still only 100. The Bench thought these estimates very reasonable and dismissed the case.

This illustration is meant to bring out the subtle quasi-independence of *stock* and *crop*. In agricultural cases we naturally think of crop as the product of sowing and growing. In animals that run wild and, as it were, sow themselves, the available crop is the "*growth*" of the stock, what the mathematicians call its differential coefficient. To show that a wild stock is depleted is still a long way from showing that its crop is less than it could be.

Data.

In 1916 Borley published an analysis and review of all the English work of marking plaice in the North Sea in pre-war years. The data refer to more than 17,000 plaice liberated on 133 separate experiments. The experiments were made in all four seasons, though of course not equally, and extended from 1903—1911. They were well enough distributed to be classified into seven sub-regions of the southern North Sea. In fact any conclusion drawn from them as a whole could

fairly be considered as applying generally to the southern North Sea in pre-war years. Borley's Table 5 is a table of double entry, in which all the data are arranged according to the calendar quarter of liberation one way and the calendar quarter of recapture the other way. The only omission was that he discarded records of fish that were returned within the quarter of liberation. The figure given is the number returned as a percentage of the number unaccounted for at the beginning of the quarter in question. The sexes are given separately. Assuming equality of the sex-ratio, the last four lines of the table can be used to reconstruct a table of actual returns, per 1,000 fish at liberty at zero time, arranging the returns in periods of three months.

	Average time from marking, in months				
	3	6	9	12	Total
Number returned in each 3-monthly period	139	91	52	40	322

These data have two peculiarities, one valuable, the other regrettable. Reconstructed as they are, from percentages within 3-month periods, they are weighted as if there had been equal marking in each quarter of the year. This will later be relied on. Their disadvantage is the discarding of returns for the quarter of liberation, so that zero time is 1½ months, on the average, from the date of liberation. This follows from the form given, that is, returns as a percentage of the number unaccounted for at the beginning of the quarter for which the percentage is given. This will introduce some error, as will be explained.

Use of the Data.

Traditional. Intensity of Fishing.

Clearly we might do no more than say that 32 % of the fish were returned within a year, and there is no objection to this statement except that it won't take us far enough. At most we can go on to say that, assuming that a certain proportion of marks are shed, that some of the fish die through marking, and that some of the marks are not returned by fishermen, then of the fish in the sea *at any given moment of time*, more than 32 % may be expected to be caught *within a year*. This has been called the "intensity of fishing". It is quite different from the "rate of fishing", except in certain special cases.

It is important to understand how this 32 % has been formed. The 1000 marked fish forthwith began to lose members, so that their number in the sea fell throughout the year of observation. The following processes caused reduction in their number:

Capture, Natural Mortality, Shedding of marks, Mortality due to marking, Loss of marks after capture.

All these processes may be presumed to act at a rate applied at compound interest, but the record of 32 % only gives us the summation of one of the processes. This is likely to be numerically very different from the rate of fishing, which, as we have seen, is a simple interest rate acting on a constant stock, not one falling from so many causes.

First Approximation to the Rate of Fishing.

We can obtain a first approximation to this rate by using only the returns from the first period of the table, in a way which may be new. The general assumption will be that rates are constant within a given period. In particular, the proportion of returns to marked fish at liberty is assumed to be constant. These assumptions apply throughout the paper, unless some other assumption is explicitly made.

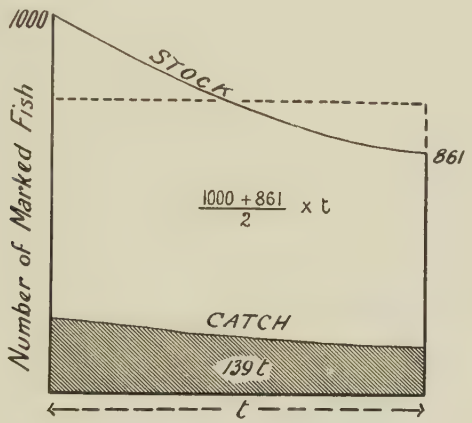


Fig. 2. Approximate Calculation of Rate of Fishing from early Returns. (Diagram *not* to scale).
The rate per time t is given by the ratio of areas representing catch and stock respectively. Data are the number, 1000, at zero time, and the returns, 139, in time t. The area under the curve of stock is approximately equal to that of the rectangle whose area is given. Error is introduced by disregarding natural mortality and accidental losses in calculating the second ordinate of stock.

The argument of the first approximation considers first the number of marked fish at liberty at the beginning and end of the first three months. At the beginning there were 1000 fish. At the end of three months there were less; 139 at any rate had been returned, so 861 were unaccounted for. Some had died naturally, some had lost their marks and some marks had not been returned, but for the present we must neglect these errors, and say that on the average $\frac{1000+861}{2} = 931$ marked fish were at liberty in the sea during the period. Of these, 139 or 14·9 % were returned during the 3-month period. The rate of fishing was, therefore, 14·9 % per 3 months, or $4 \times 14{\cdot}9 = 60$ % per annum. The validity of this calculation can be checked by reference to a diagram, Fig. 2. Had these data referred to a single experiment made in one time and place, we could then say, and could say only, that the rate of fishing for that ground and season was greater than 60 % per annum. In regard to these particular data, the fact that

they came from so many grounds and seasons makes the answer generally applicable.

Failure to take account of deaths from natural causes in calculating the number of survivors at the end of the 3-month period tends to make the answer too low. In addition something must be added for deaths due to marking, loss of marks, and failure to return marks.

This first approximation is as far as we can go without introducing a new calculation, to which we now proceed.

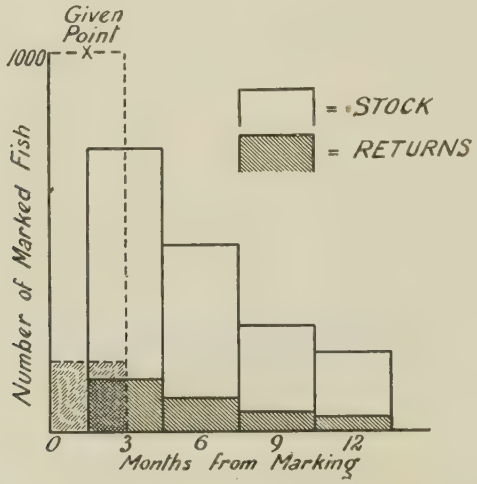


Fig. 3. Determination of Rate of Fishing by Extrapolation of Returns to Time Zero. Data are the shaded areas representing returns in successive periods and the point shown by a cross, which gives the number at time zero. The aim is to find the ratio of the area representing returns at time zero to the corresponding area representing the stock of marked fish. There is a fuller explanation in the text. For these data time zero was at 1½ months from marking, which makes the result somewhat in error in this case, but leaves the method valid.

Method proposed for Rate of Fishing.

A little consideration shows that the vital moment of our experiment is at time zero. Then, and then only, did we know the number of marked fish in the sea. From this point of view we would like to consider returns from a very short period of the experiments, for example, for the first day; but if we did such a thing in fact, we should waste all the rest of our data, and also introduce enormous sampling error. We can, however, return to this first moment graphically, with the help of all our data, and that is the principle of the new calculation. Knowing that at time zero there were 1000 marked fish, *we shall come back along the curve given by all the returns plotted against time, so as to obtain the return at time zero.*

We could return along the curve of returns by freehand drawing. In Figure 3 the data are represented by columns, the tall column for

the period 0—3 months representing the number at time zero, the short shaded columns centred on 3, 6, 9, and 12 months, representing recaptures. The aim is to find how high to draw the short column of recaptures for the period centred on time zero, in this case 0—3 months, as was explained in describing the data. Usually it would be — 1½ to + 1½ months from the actual date of release. The method is to use the heights of the shaded columns as data for a slight extrapolation to give the height of a corresponding column at time zero. The remaining columns of stock may be drawn, for the sake of completing the picture, using the proportion in 0—3 months. The following calculation uses some computation to enable the extrapolation to be made on a straight line.

	Average time from marking, in months							
	1½	3	4½	6	7½	9	10½	12
(1) Returns	—	139	—	91	—	52	—	40
(2) Common Logs	—	2·1430	—	1·9590	—	1·7160	—	1·6021
(3) Difference of Common Logs	—	—	0·1840	—	0·2430	—	0·1139	—
(4) Difference of Napierian Logs	—	—	0·4236	—	0·5596	—	0·2624	—
(5) Ratio of Common Logs	—	—	0·91	—	0·88	—	0·93	—
(6) Logs of Logs (Common)	—	0·3310	—	0·2920	—	0·2345	—	0·2046
(7) Interpolation in (6) from a graph	—	—	0·311	—	0·266	—	0·221	—
(8) Extrapolation in (6) from a graph	0·356	—	—	—	—	—	—	—
(9) Antilogs of (7) and (8)	2·270	—	2·046	—	1·845	—	1·663	—
(10) Antilogs of (9)	186	—	111	—	70	—	46	—

The returns in line (1) are falling, and, we repeat again, it is assumed that the marked stock is falling with them, that is, the returns are a constant percentage of the marked stock. This assumption is fair, in so far as the experiments were many and widely scattered as to season and ground, and the data have been reconstructed from a table in which the marking of each quarter has equal weight. The lines (2), (3), (5), and (6) are simply trials to determine the form of the rate of fall shown in line (1). Lines (3) or (4) show that the rate is not constant, so the general assumption we should like to use is inapplicable in this case. Line (5), however, shows that the deceleration is nearly enough constant, on the basis of which a straight line was drawn on squared paper near points given by line (6). Lines (7) and (8) give new points on the graph, and lines (9) and (10) the corresponding values to supplement those of lines (2) and (1). Had line (3) shown constancy, interpolation could have been carried out in line (2). The number returned per 3 months at 1½ months from marking is found

to be 186, so the rate is $4 \times \frac{981}{1000} = 0{\cdot}744$ or 74 % per annum. The error due to time zero not being at the instant of marking is that this 1000, unaccounted for at the beginning of the first quarter for which there are returns, really represents a less number in the sea, owing to losses in the quarter of marking.

Discussion.

Some Implications.

It cannot be too strongly emphasized that the foregoing calculation is only valid in so far as seasonal variations in rate of fishing have been eliminated. That is to say, in practice, data will be needed from experiments extending over several years. During such a period it is difficult, but it is essential, that the whole technique of marking and obtaining returns be kept as nearly constant as possible; otherwise the work would not be evenly spread. During the experiment attempts to improve the technique could do a lot of harm. It is not easy to see how fishermen's attention to return of marked fish could be kept constant, but any obvious irregularities in publicity should be avoided, such as an initial advertising campaign not afterwards sustained. It is also clear that the area and type of fishery to be investigated must be decided in advance and the experiments spread within this fishery as well as may be done. It seems, for example, wrong to go only to places where the fishermen are catching fish in large quantities, for there the rate of fishing will be higher than elsewhere in the chosen area, but it would be still more wrong to avoid such places.

This emphasis on technical constancy, rather than improvement of methods, may be rather surprising; and in support of it, it may be worth while to illustrate by an example that the estimate of rate of fishing is hardly affected by shedding of marks and other accidental losses, provided these losses are fairly regular. For example, the method was applied to the returns of two imaginary cases, in both of which the rate of fishing used in constructing the cases was 0·4. In both also a rate of natural mortality of 0·4 was used. In one there was no shedding of marks, nor any other loss. Application of the calculation, extrapolating in this case on the logarithms of the returns, gave a rate lying between 0·39 and 0·41, that is a very good estimate. In the second case the rates used in building up the case were the same, except that the extreme rate of 0·8 was also applied to represent shedding of marks and other losses. Even in such a case, the answer was almost exactly correct, the limits of drawing a straight line near the logarithms giving values of 0·39 and 0·40.

Thompson and Herrington's arrangement of marking experiments is noteworthy in attempting to fulfill the conditions which seem to be necessary.

Special Cases of Marking Experiments.

There are two special cases where it also seems good to continue to mark fish at a constant rate, but which have interesting and peculiar features. In one there is no seasonal variation, neither in breeding nor in fishing; in the other the whole fishery is strictly seasonal.

Tilapia esculenta of the Victoria Nyanza may be taken as an example of what must apply to many tropical fish. No variation in breeding nor in fishing was found during seven months, and enquiry did not produce any account of such variation in the remaining five months of the year (G r a h a m, 1929). In this case marking at a constant rate would result in the return from marking being directly equal to the rate of fishing, after the work had gone on for some time. If a number of marked fish *a* falls to *b, c, d, e* and nil, in successive months and *a* are marked every month, a table may be made, of which the sums, vertically, show the number at liberty in successive months.

Number of marked fish at liberty in successive months, from marking of *a* fish in each month:

a	*b*	*c*	*d*	*e*						
	a	*b*	*c*	*d*	*e*					
		a	*b*	*c*	*d*	*e*				
			a	*b*	*c*	*d*	*e*			
				a	*b*	*c*	*d*	*e*		
					a	*b*	*c*	*d*	*e*	
						a	*b*	*c*	*d*	*e*

Between the period when the last of the fish first marked come in and the date of the last marking, the number of marked fish at liberty is constant, as is shown by the sums, vertically, of the above table. During this period the number at liberty is, therefore, proportional to the constant stock, and the rate of return of marked fish is the same as the rate of fishing, when both are expressed as percentages. In practice, however, an investigator could take advantage of absence of seasonal variations to use a marking experiment of limited duration, because in this case he would be justified in extrapolating to time zero on those data alone, without the spreading of marking in time, which is necessary when there is seasonal variation.

In the opposite case, where the fishery is confined to one short season, the correct procedure will depend on circumstances, and there is no point in constructing theory in the air. But it may be noted that if one short marking experiment is made near the beginning of the season the percentage of marked fish returned during the season probably has a useful meaning. Assuming that the fate of first-comers is not different from that of late-comers, we should obtain the percentage of all the fish that come to the ground that are taken by the fishery. One must be wary of continuing the marking unless quite certain, as one could be in a salmon estuary, that one is marking only

new-comers. As an example of the difficulties, we note that not all the spawning cod of Lofoten come to the banks that are fished (S u n d, 1935). On the other hand regular marking throughout the season would give a result in terms of density of stock that is there at any one time, by the methods now proposed. How useful each of these results might be, would depend on the circumstances of particular cases.

Natural Mortality.

The rate of natural mortality is usually best obtained by subtracting the rate of fishing from the rate of general mortality, obtained from tables of age composition. Thus, if the average relative numbers of III-group and IV-group fish are 60 and 20, the following calculation gives the rate of general mortality, including fishing and death from natural causes, at 4 years of age:—

	Frequency	Common Log	Common Log/0·4343
III-group	60	1·7782	4·09
IV-group	20	1·3010	3·00
		Difference	1·09

$$(60\, e^{-r} = 20,\ r = \log 60 - \log 20)$$

The rate of general mortality is, therefore, 109 % per annum, this, again, being an instantaneous rate[1]). If the fishing rate of 74 % that we have found for pre-war plaice applies to this group, the difference, 35 % is attributable to natural mortality.

There are, however, fish — for example, in the tropics — that could be marked, but of which a census by age is impracticable. In such a case, and even in ordinary cases, as an independent line of evidence, the data of marking experiments can give some estimate of natural mortality.

Returning to line (4) of our working table, we see that the returns were falling at rates, per 3 months, of:—

0·4236 0·5596 0·2624

These measure not only general mortality, but also loss of marks by shedding, mortality due to marking and non-return of marks, but, on the assumption that the marked stock is representative of the whole stock, the figures may be used as an approach to the rate of general mortality. It is considered that the last is probably most free from the effects of mortality due to marking and shedding of marks. We have 0·2624 per 3 months, or 1·05 per annum. Subtracting 0·74 from 1·05 we obtain 0·31 or 31 %, as an overestimate of the rate of natural mortality.

[1]) See above, or consider that a lawn is mowed at, say, 50 % per week, or 2600 % per annum, during the growing season.

Transplantation.

The foregoing calculations yield the estimates required in the over-fishing problem. There is, however, one problem that requires the returns from marking experiments in the traditional form, namely the total number of fish returned within a year. This is the problem of estimating the yield from transplantation; and we are now in a position to suggest an improvement that can be used when there is also an *independent* estimate of natural mortality.

In estimating the benefit of transplantation, the marked fish are, at all times, a sample of the population that we wish to investigate. Only, as an improvement on the direct and older method of estimating the returns, we may, in certain cases, correct the figure of 32 % to allow for the accidental losses of marks, and so on. We have found that the rate of fishing of a constant population was 0·744 per annum. So long as the stock remains constant, the yield is given by the application of this rate at simple interest, but the stock of transplanted fish is falling all the time, by fishing and natural mortality, and the rate must be applied at compound interest. Supposing that we have found the rate of natural mortality, by the best method from the census by age, to be 35 % per annum, the following calculation gives the survivors, S_2, at the end of one year:—

$$100_e^{-(0\cdot74\ +\ 0\cdot35)} = S_2;\ (\log_e 100 = 4\cdot61)$$
$$\log_{10} S_2 = (4\cdot61 - 1\cdot09)\ 0\cdot4343$$
$$= 1\cdot529$$
$$S_2 = 33\cdot8$$

If the survivors are 33·8 %, those captured and dead from natural causes are 66·2 %. This number must be divided in the ratio of the respective rates, that is, 74:35. This makes the number captured 45. This figure, 45 %, is a better estimate of the return from transplantation than the figure that was reduced by accidental losses. Its determination involves, however, knowledge of the rate of natural mortality.

Summary.

A method is suggested for calculating the "rate of fishing", which is defined, from marking experiments which have been carried out at all seasons of the year. Marking experiments of more limited duration are also considered; but it is emphasized that the work should be continuous and carefully arranged to provide as nearly constant technique as possible. In this case imperfection of technique is unimportant.

A method is also suggested for obtaining an over-estimate of the rate of natural mortality from marking experiments alone, for cases where census by age is impracticable.

An improvement is proposed for estimating the yield from trans-plantation.

References.

Baranov. On the Question of the Biological Basis of Fisheries. Moscow, 1916.
Borley. Min. Agric. and Fish., Fish. Invest. II, III, 3. London, 1916.
Graham. *ibid.*, II, VI, 6, p. 49, 1924.
Graham. The Victoria Nyanza and its Fisheries. Crown Agents. London, 1929.
Graham. Journ. du Conseil, X, 3, p. 264. Copenhague, 1935.
Wollaston. Min. Agric. and Fish., Fish. Invest. II, XIII, 1, p. 9. London, 1933.
Thompson and Herrington. Rep. Int. Fish. Comm. II, p. 70. Victoria, 1930.
Sund. Årsberet. Norges Fisk., 2. Bergen, 1936.

On the Size and Number of the Ova of Irish Herrings.

By

G. P. Farran,

Department of Agriculture, Fisheries Branch, Dublin.

FOR some time past it has been the practice, when a sample of Irish herrings was examined by the staff of the Fisheries Branch, to measure the diameter of the eggs of a small number of females, in order to obtain data which might be useful in checking the estimates of maturity made by the generally accepted scale of I to VII.

It soon became evident that the size of the ova when compared with the weight of the gonad relative to the length of the fish, using the formula $K_G = \frac{\text{weight of gonad} \times 100}{L^3}$, showed such wide variations that the diameter of the ova could not be used directly to give an effective diagnosis of the stage of maturity.

On a recent attempt to investigate this variation further it became evident that there were two definite size-groups amongst the eggs, and that all herrings known to be spring spawners had the larger eggs, while the eggs of the autumn spawners were distinctly smaller. Samples whose time of spawning was not certainly known belonged definitely to one or other size-group and it has been assumed that they were respectively spring or autumn spawners.

If this observed difference should be found to hold good for other localities it may furnish a convenient method of distinguishing between different stocks of herrings at any stage of maturity, less troublesome than vertebral counts, since smaller numbers of fish are required; and for this reason attention is called to it here without waiting for the accumulation of data which a full investigation of its implications would demand.

The difference in size of the eggs of herrings from different places has often been alluded to, and as early as 1878 K u p f f e r pointed out that the eggs of Norwegian herrings were much larger than those

from the Baltic, but I have not seen any references to a difference between the eggs of spring and autumn spawners from the same locality. The routine adopted in making the measurements was to measure the total length of the fish to the nearest millimetre from the snout to the tip of the longest tail-ray bent up or down, to weigh the gonad to the nearest gramme, or, if small, to the half-gramme, and to tease out a small portion of the ovary in 10 per cent. formalin for subsequent measurement. The eggs were measured under the microscope with a squared eyepiece, to the nearest .01 mm., twenty of the most nearly spherical ova being selected at random and the average diameter taken.

There are some small sources of error in ascertaining the value of K_G. The most serious is shrinkage in length of the fish, which may amount to 4 mm.; in addition to this, errors of measurement might amount to 2 mm., giving a range of error for a fish of 25 cm., of 24·4—25·2 cm. The gonad might possibly be referred to the gramme weight above or below the true weight, e.g., 18 gm. might be recorded as 17 or 19. Consequently a fish of 25 cm., gonad 18 gm., might be recorded as 24·4 cm. gonad 19 gm., K_G 13·1, or 25·2 cm. gonad 17 gm., K_G 10·6.

These errors, though insufficient to account for the whole variation, may help to account for some of the wide divergences from the averages.

The diagram (Fig. 1) shows the measurements of the ova plotted against the values of K_G for all the fish measured. It shows plainly the difference in size of the eggs in the two size-groups. The broken lines in the diagram are not the means of the two groups but are equivalent to $\sqrt[3]{K_G}$ in units corresponding to the diameters of the eggs. The observed sizes of ripe, i.e., running, ova are shown on the right of the diagram. The K_G for these, owing to the loss of ova, is irrelevant.

This method of tabulating the measurements and weights is only justified on two assumptions, one that the specific gravity of the ova remains more or less constant during development, and the other that the weight of the ovary at any given stage of ripeness is proportional to L^3 for all sizes of fish. This latter assumption, as will be shown later, is not correct, but it is sufficiently accurate within the general run of sizes met with to allow of its use as a preliminary diagnosis of the type. It will be noticed that no ripe ova of autumn spawners were obtained, but it is clear that they can never attain the size of those of spring spawners for in that case the weight of the ovary would amount to about 50 per cent. of the total weight of the fish.

The following are the particulars of the samples from which the measurements were taken, and in the table which follows, the average diameters of the ova in the various samples are given for successive values of K_G, the number of fish on which the values are based being given in brackets.

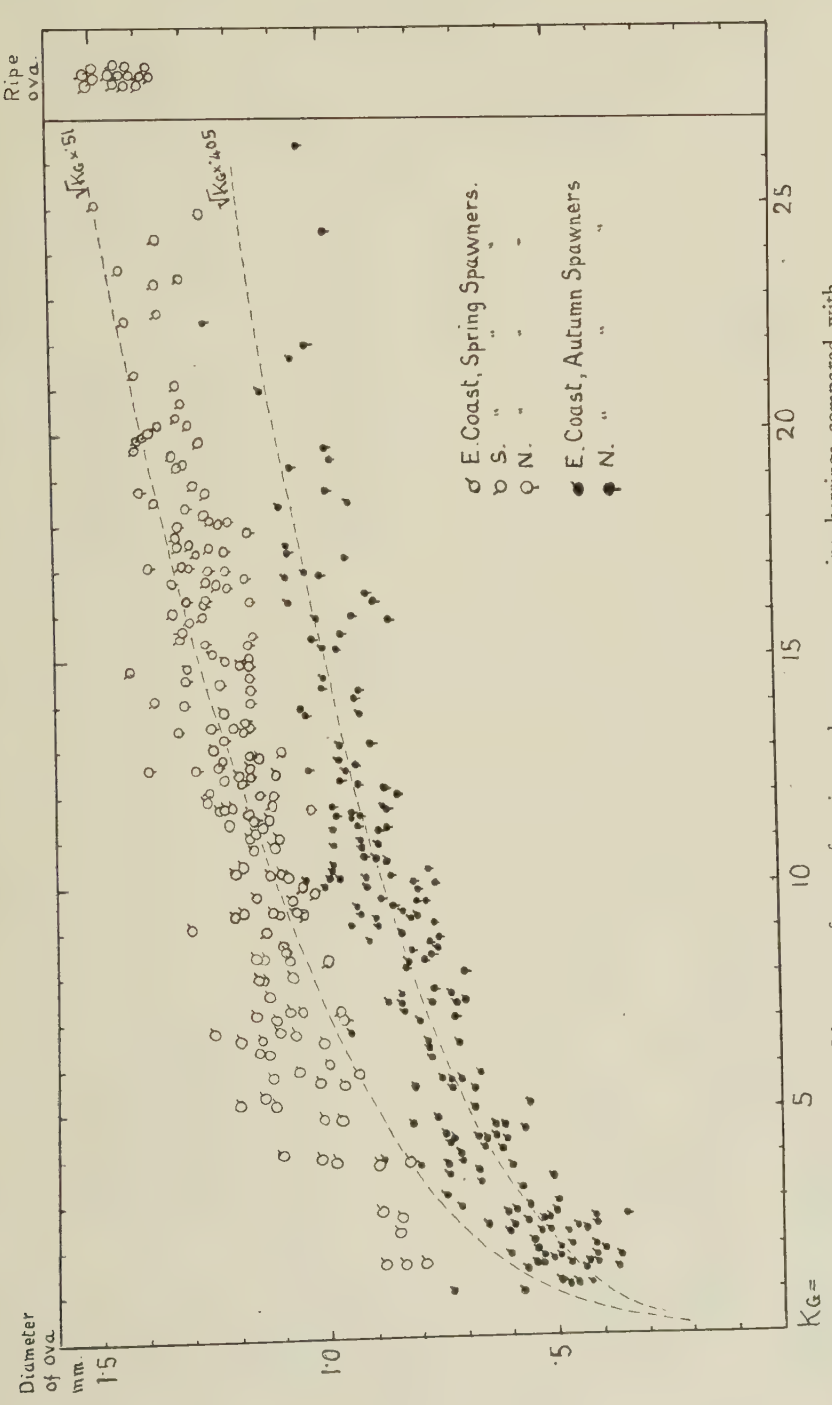


Fig. 1. Diameters of ova of spring and autumn spawning herrings compared with K_G of ovaries.

Spring Spawners.

1.	East Coast	(Arklow)	21/12/31, 33 fish,	21·2—25·9 cm.
2.	„ „	(Dublin Bay)	10/11/33, 17 „	21·5—26·5 cm.
3.	„ „	(Rosslare)	23/11/33, 31 „	21·7—25·5 cm.
4.	South „	(Dunmore)	5/11/34, 18 „	24·3—27·6 cm.
5.	„ „	(„)	22/ 1/35, 12 „	26·7—29·7 cm.
6.	„ „	(„)	15/ 1/37, 50 „	26·0—31·4 cm.
7.	North „	(Buncrana)	28/ 1/37, 50 „	29·0—34·5 cm.

Autumn Spawners.

1.	East Coast	(Howth)	6/8/35, 15 fish,	22·1—27·9 cm.
2.	„ „	(„)	5/9/35, 12 „	22·3—26·2 cm.
3.	„ „	(„)	15/7/36, 19 „	24·1—29·0 cm.
4.	„ „	(„)	18/6/37, 22 „	23·1—26·4 cm.
5.	„ „	(„)	20/7/37, 48 „	22·2—28·6 cm.
6.	„ „	(„)	16/9/37, 48 „	23·1—29·2 cm.
7.	North „	(Downings Bay)	23/9/35, 10 „	26·8—30·1 cm.
8.	„ „	(Lough Swilly)	16/9/37, 50 „	23·2—30·3 cm.

Table 1.

Spring Spawners.

Average Diameter of Ova at Successive Values of K_G.

Sample No.	1	2	3	4	5	6	7
K_G = 1·5	—	·84(3)	—	—	—	—	—
2·5	—	·86(3)	—	—	—	—	—
3·5	—	·89(1)	·90(2)	—	—	—	—
4·5	—	1·04(3)	1·03(2)	—	—	—	—
5·5	—	1·04(2)	1·08(5)	—	—	—	—
6·5	—	1·20(2)	1·09(8)	—	—	—	—
7·5	—	1·14(2)	1·11(3)	·98(2)	—	—	·96(1)
8·5	1·11(6)	—	1·07(1)	1·00(1)	—	—	—
9·5	1·11(4)	1·30(1)	1·18(3)	1·07(3)	—	—	1·06(1)
10·5	1·15(3)	—	1·22(4)	1·05(1)	—	—	—
11·5	1·18(9)	—	1·12(2)	1·21(2)	—	—	1·13(3)
12·5	1·19(4)	—	1·14(2)	1·18(2)	—	1·25(1)	1·23(6)
13·5	1·23(2)	—	—	1·15(1)	1·10(1)	1·25(1)	1·20(8)
14·5	1·24(2)	—	—	1·21(3)	1·36(1)	—	1·21(7)
15·5	1·21(1)	—	—	1·23(1)	—	1·30(3)	1·19(3)
16·5	1·26(1)	—	—	1·24(1)	—	1·28(3)	1·25(9)
17·5	—	—	—	—	1·31(1)	1·31(5)	1·26(7)
18·5	—	—	—	—	1·27(1)	1·27(5)	1·27(5)
19·5	—	—	—	—	1·28(1)	1·33(6)	—
20·5	—	—	—	—	1·32(3)	1·34(5)	—
21·5	—	—	—	—	—	1·35(2)	—
22·5	—	—	—	—	1·39(2)	—	—
23·5	—	—	—	—	—	1·37(3)	—
24·5	—	—	—	—	1·27(1)	1·37(1)	—
Spawning	—	—	—	1·48(1)	—	1·43(14)	—

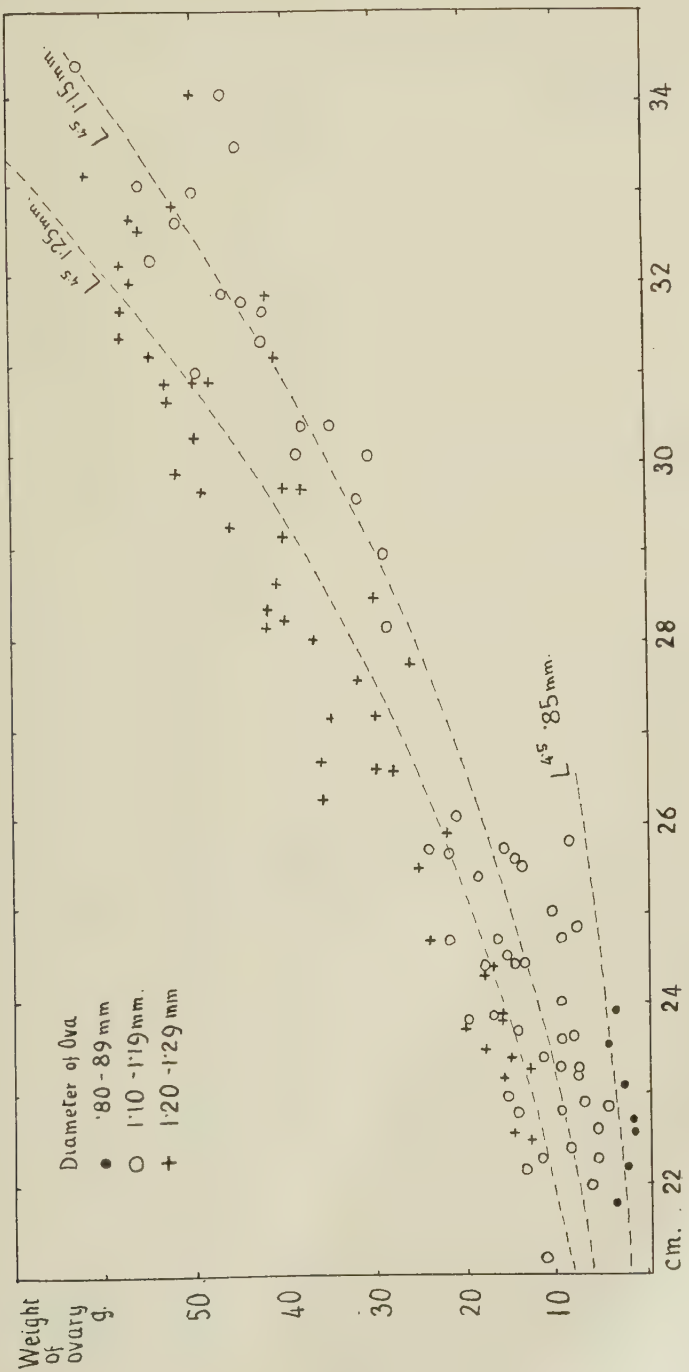


Fig. 2. Weights of ovaries of spring spawning herrings compared with length of fish, for ova of different diameters.

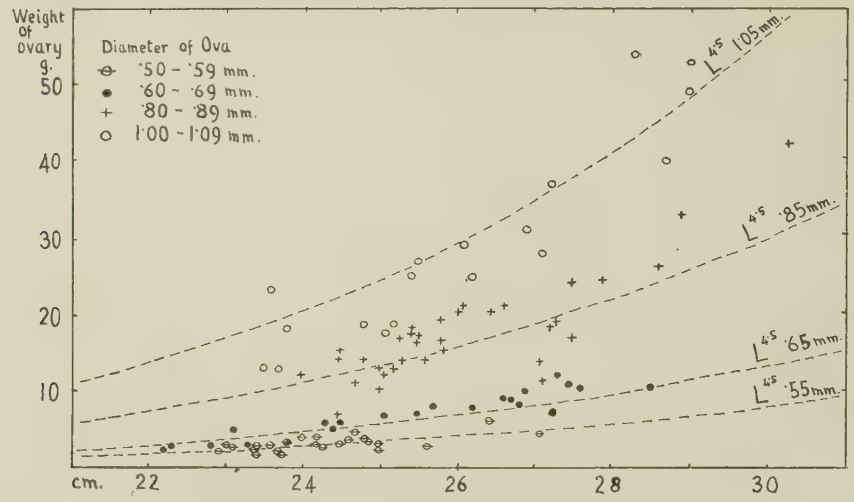


Fig. 3. Weights of ovaries of autumn spawning herrings compared with length of fish, for ova of different diameters.

Table 2.

Autumn Spawners.

Average Diameter of Ova at Successive Values of K_G.

Sample No.		1	2	3	4	5	6	7	8
K_G	1·5	·62(3)	—	·43(1)	·44(6)	·52(14)	·52(2)	—	·36(1)
	2·5	—	—	—	·48(15)	·59(9)	·72(1)	—	—
	3·5	—	·79(1)	·66(3)	·51(1)	·70(5)	·75(2)	—	—
	4·5	—	·75(1)	·65(4)	—	·66(9)	·78(2)	—	—
	5·5	·78(2)	—	·67(4)	—	·68(3)	·76(1)	—	—
	6·5	·79(1)	·82(1)	·78(2)	—	·76(2)	·85(3)	—	·75(3)
	7·5	·81(1)	·86(2)	·74(4)	—	·75(2)	·84(1)	—	·78(7)
	8·5	·81(3)	—	—	—	·79(1)	·92(4)	—	·84(6)
	9·9	—	·98(1)	—	—	·83(2)	·93(4)	—	·83(6)
	10·5	·88(3)	—	—	—	—	·95(9)	—	·93(6)
	11·5	·95(1)	·94(3)	·87(1)	—	·82(1)	·90(3)	·94(1)	·96(7)
	12·5	·96(1)	—	—	—	—	1·01(3)	—	·90(1)
	13·5	—	1·00(1)	—	—	—	·93(2)	1·05(1)	·96(3)
	14·5	—	—	—	—	—	1·00(5)	—	·92(2)
	15·5	—	—	—	—	—	1·01(2)	·97(1)	·94(3)
	16·5	—	—	—	—	—	1·07(3)	·94(1)	·95(1)
	17·5	—	—	—	—	—	1·08(1)	1·08(1)	·99(1)
	18·5	—	—	—	—	—	1·02(1)	—	·99(2)
	19·5	—	—	—	—	—	—	1·08(1)	—
	20·5	—	—	—	—	—	1·13(1)	—	—
	21·5	—	—	—	—	—	1·06(1)	—	—
	22·5	—	—	—	—	—	—	1·15(2)	—
	23·5	—	—	—	—	—	—	—	1·02(1)
	24·5	—	—	—	—	—	—	1·00(1)	—
	25·5	—	—	—	—	—	—	—	—
	26·5	—	—	—	—	—	—	1·05(1)	—

The measurements can be considered from another point of view. Taking the distinction between the eggs of spring and autumn spawners as proved, we may for each class plot, for ova of a given diameter, the weight of the gonad against the length of the fish, assuming in this case that, in each group, the size of the ovum represents a definite stage in development. In the graphs (Figs. 2 and 3) this has been done for selected sizes of eggs.

It is evident from these graphs that the relationship $\frac{\text{weight of ovary}}{L^3}$ is not a constant value for any definite stage of maturity, but that the weight of the ovary increases more rapidly than L^3 or, in other words, than the size of the fish.

As a preliminary estimate it is suggested that the weight of the ovary at any given stage of maturity is proportional to $L^{4\cdot5}$, and the broken lines shown on the graphs represent that proportion expressed in units corresponding to the size of the ova, the units at any length being directly proportional to the diameter of the ova; or, more concisely, they represent $\frac{cL^{4\cdot5} \times d^3}{10{,}000{,}000}$ where d is the diameter of the ova and c is a constant, $= 52$ in the case of spring spawners and $= 110$ in the case of autumn spawners, the length being given in centimetres, the diameter of ova in millimetres and the weight in grammes. These figures were taken, without mathematical proof, as giving a satisfactory agreement with the distribution of the points on the graphs.

It will be noticed that although the samples of both spring and autumn spawners come from widely separated sources they all fall into position more or less accurately in their respective diagrams.

Any marked divergence of the points on the graph from the broken lines should indicate that the assumptions that have been made are not accurate. The most noticeable divergence is in the case of the largest fish whose ovaries in the advanced stages drop below the line, i.e., show a falling off in weight. It is suggested that this is because very large fish do actually show a smaller increase in the size of their ovaries than is indicated by $L^{4\cdot5}$.

The data may be considered in a third way. Assuming that the weight of the ovary for fish of any particular length represents a definite stage of ripeness, it has been shown that the spring spawners have consistently larger eggs, i.e., for a fish of the same size and weight of ovary the eggs of a spring spawner are approximately 25 per cent. larger in diameter. It follows that, if the specific gravity of the eggs is the same, the volume of an egg in the spring spawner is almost twice as great, i.e., 195 : 100 and consequently the number must be about half as large, i.e., $\frac{10}{19\cdot5}$. From the fact that all the ripening eggs in an ovary are approximately of equal size it may be inferred that the numbers destined to ripen in any breeding cycle are fixed from the time that the storage of yolk has begun. Consequently if the

specific gravity of the eggs, or, in other words, the weight of a given number at a given size, is known we can ascertain the actual number of eggs in an ovary if the weight of the ovary and the diameter of the eggs are known. An actual count of a carefully weighed fraction, about $\frac{1}{20}$, of three ovaries of Howth herrings, taken 16th September 1937, gave the following results:—

	Length	Weight of Ovary	Diam. of Ova	Estimated Number of Eggs
(a)	25·4 cm.	16·60 gm.	·991 mm.	36530
(b)	28·4 cm.	23·65 gm.	·991 mm.	52570
(c)	29·0 cm.	47·50 gm.	1·132 mm.	70120

These counts gave the following values for X in the equation

$$\text{Number of eggs} = \frac{\text{wt. of ovary} \times X}{\text{diameter}^3} :—$$

(a) 2162·9 (b) 2143·5 (c) 2141·2

An average value for X of 2150 has been taken, and this value has been applied to fish from selected samples from those mentioned above, for the purpose of estimating the total numbers of ova. Fish with ripe ova or with very small ovaries have been omitted. In the diagram (Fig. 4) the numbers of ova so obtained have been plotted against the length of the fish. The broken lines shown in the diagram correspond to $L^{4·5}$.

It should be noted that in this procedure no new data have been introduced other than the approximate value for the specific gravity of the ova, which is assumed to apply to all stages of maturity of any fish.

This diagram brings out more clearly what was deduced from the figures given earlier in the paper, namely, that the number of eggs in the autumn spawners is almost twice as great as in the spring spawners, and also that the rate of increase in number in fish over 32 cm. in length ceases to correspond to the increase in length and either falls off considerably or ceases altogether.

It will be noticed that there are small discrepancies between the results obtained from these three methods of treatment. In Fig. 1 the comparative diameters of the ova of spring and autumn spawners are shown as having the ratio of 405 to 510, which is equivalent to a difference in size of 1 to 2. In Figs. 2 and 3 the most satisfactory expression of the ratio of the weights of the ovaries appears to be 10 to 21, and in Fig. 4 the difference in numbers of ova was as 25 to 58. Most, if not all, these discrepancies are no doubt due to the rule-of-thumb methods used in dealing with the data.

It follows from the figures which have been given that, taking both spring and autumn spawners together, the size of the eggs is not a measure of the stage of ripeness, but for each group separately the choice is open between the size of the eggs and the weight of the ovary

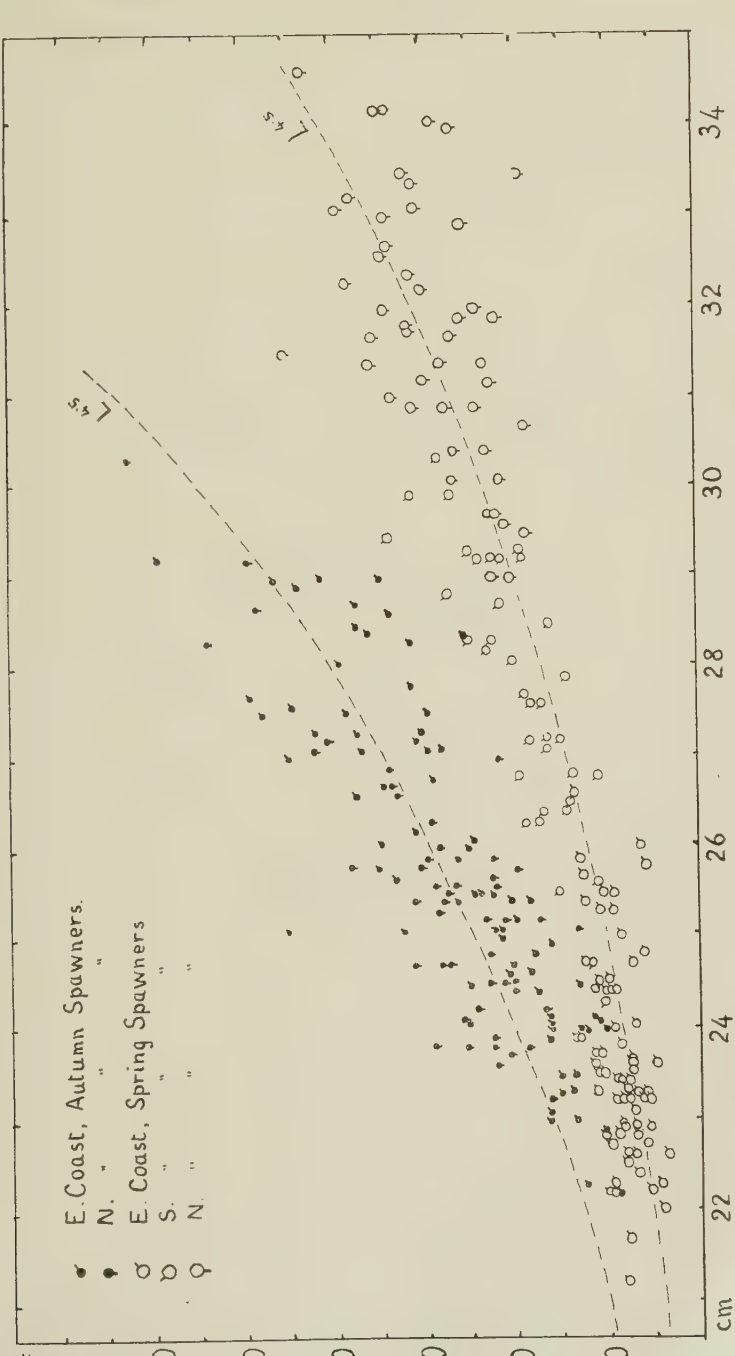


Fig. 4. Numbers of active ova (thousands) in spring and autumn spawning herrings at successive lengths.

as an indicator of ripeness, the data available up to the present being insufficient to decide between them; for we cannot yet say, as between two herrings of the same size, one with more numerous ova than the other, whether the ripe eggs of the former will be smaller than or of the same size as those of the latter or whether size and number both vary independently round a mean.

The primary cause of the difference between the spring and the autumn spawners must surely be looked for in a genetic difference which induces a difference in habit, but it seems possible that the conditions under which development of the ova commences and is carried on may have some effect on their number and size. The recovery of the ovary and development of the new crop of eggs appears to take place very shortly after spawning, and in the case of the spring spawners this usually occurs when the temperature of the sea is at its minimum or is just beginning to rise, while the autumn spawning occurs while the temperature is still high but has begun to fall after its summer maximum.

Summary.

The spring and autumn spawning Irish herrings, so far as they have been examined, can be separated at any stage of maturity by the size of the ova in relation to the weight of the gonad.

For fish of the same size the ova in an ovary of any given weight are approximately 25 per cent. larger in spring spawners than in autumn spawners and about half as numerous.

The weight of the ovary for ova of the same size is approximately proportional to $L^{4\cdot5}$ for both spring and autumn spawners.

The number of ova is proportional to $L^{4\cdot5}$ for both spring and autumn spawners.

There are indications that there is a falling off in the numbers of ova in proportion to the length of the fish in fish of above 32 cm. in length.

Reviews.

G. Schott. "Geographie des Indischen und Stillen Ozeans." S. 413, Fig. 114, Taf. XXXVII. C. Boysen, Hamburg, 1935.

Schott's well-known volume on the Atlantic Ocean has been so universally considered a standard and fundamental piece of work that all students of geography, meteorology, and oceanography will welcome with enthusiasm his new companion study of the Indian and Pacific Oceans. The least that can be said is that these two volumes reflect the whole range of modern knowledge concerning the three major oceans. They are the work of a most careful and thorough student who at the same time loves and knows the sea from the sailor's point of view. Thus the information contained in these two volumes not only is of great importance to scientists, but also to travellers and sailors and, for that matter, to anyone having the least curiosity about the sea.

It will be impossible here to attempt to cover the full scope of the new volume. The reviewer's remarks will be therefore confined to its more strictly oceanographical aspects.

The first chapters deal with the history of the discovery and exploration of the Indian and Pacific Oceans, their limits and sizes, their geology, coastlines, islands, volcanoes, etc. Then comes a chapter on depths and bottom deposits which is accompanied by a large, coloured, bathymetric chart that deserves special mention as being outstanding among the other 36 beautifully executed plates. There follows a full description of the meteorological and oceanographical properties of the surface. Charts are presented showing air temperature and water temperature for February, May, August, and November, as well as winter and summer values for barometric pressure, storminess, cloudiness, etc. The available subsurface observations of temperature and salinity are both plotted in section and, in the case of temperature, in horizontal projection (200 and 400 metres), as well as being summarized in tables which show their vertical distribution and the subsurface temperature-salinity correlation for representative regions.

Perhaps the most outstanding and original contribution of the author's studies is his subdivision of the oceans into natural regions from the geographic standpoint. He has charted and discussed 8 such regions in the Indian Ocean and 13 from the Pacific. The physical characteristics (for example, climate, currents, winds, seasonal cycle, and ice) of each of these regions are described in two chapters that total 120 pages.

Of the remaining chapters, one written by E. Hentschel deals with the marine life of the Indian and Pacific Oceans, while the other covers the early migrations of the native population and the commercial factors such as trade routes and fisheries. An ample bibliography is given at the end of each of the 11 chapters.

In short, this new book provides not only a complete meteorological and oceanographic atlas, but also a careful descriptive treatment of nearly all that is known about an immense, but relatively unstudied, part of the earth's surface. It is greatly to be regretted that such a full study of the ocean areas is not available also in English.

C. O'D. I.

G. E. R. Deacon. "The Hydrology of the Southern Ocean." "Note on the Dynamics of the Southern Ocean." Discovery Reps., Vol. XV, pp. 1—152, 26 figs, plates I—XLIV. Cambridge, 1937.

Die ausgedehnten ozeanographischen und planktologischen Untersuchungen, die das Discovery Committee seit 1925 in den südlichen Teilen des Südatlantischen Ozeans und in den angrenzenden Teilen des Indischen und Pazifischen Ozeans ausgeführt hat, wurden in den Jahren 1932—33 vervollständigt durch eine ausgedehnte zirkumpolare Fahrt um die Antarktis, die durch ihre Planlegung von früheren Fahrten wesentlich abwich und in ihrer Durchführung ein gänzlich neues, für die Kenntnis der Ozeane rund um die Antarktis grundlegendes ozeanographisches Beobachtungsmaterial lieferte. Die Arbeitszeit im Indischen und Pazifischen Sektor fiel auf die Wintermonate und bietet deshalb besonderes Interesse, da wir dadurch wenigstens einigermassen über den Aufbau des Meeres dieser Gegenden in der kalten Jahreszeit unterrichtet werden.

In der ersten der oben zitierten Abhandlungen gibt nun Deacon eine eingehende Analyse des auf diesen Fahrten gewonnenen Beobachtungsmaterials, wobei er völlig auf dem Standpunkte moderner dynamischer Auffassung der ozeanographischen Erscheinungen steht. Diese Analyse führt, wie zunächst nicht anders zu erwarten ist, nur zu qualitativen Ergebnissen und gipfelt in der Diskussion der 5 Wasserarten und ihrer räumlichen Verbreitung im untersuchten Gebiet rund um die Antarktis, nämlich 1. des antarktischen Oberflächenwassers, 2. des subantarktischen Wassers, 3. des subtropischen Wassers, 4. des warmen Tiefenwassers und endlich 5. des antarktischen Bodenwassers. Es ist erfreulich zu sehen, wie Deacon in der Durchführung der Analyse dieser Wasserarten sich im wesentlichen derselben Methoden und Schlussfolgerungen bedient, die auch bei der Bearbeitung des Beobachtungsmaterials der Deutschen Atlantischen Expedition auf dem "Meteor" Verwendung fanden, und dass das gewonnene Bild der ozeanischen Zirkulation dieser hohen südlichen Breiten mit den unseren vom "Meteor"-Material abgeleiteten völlig übereinstimmt. Insbesondere ist als wichtigstes Ergebnis hervorzuheben, dass im wesentlichen in allen drei Ozeanen die hohen Südbreiten denselben Aufbau des Meeres aufweisen und damit wohl auch die Bewegungen, die zu diesem führen und mit ihm verkoppelt sind, derselben Art sind. Wir gewinnen durch diese Bearbeitung ein Bild des erdumfassenden ozeanischen Geschehens im antarktischen Meere und die ursächliche Verknüpfung der einzelnen Glieder dieser Zirkulation, zwar nicht auf quantitativer dynamischer Grundlage, so doch innerlich in sich geschlossen und in allen Teilen sich gegenseitig stützend. Von besonderem Wert sind die auf 54 Tafeln gegebenen Temperatur-, Salzgehalt- und Sauerstoffschnitte für 19 Profile, die — und dies ist besonders wichtig — in der Mehrzahl mehr oder minder meridional verlaufen; von denen liegen 7 im Südatlantischen, 4 im Südindischen und 8 im Südpazifischen Ozean.

In der zweiten der oben zitierten Abhandlungen gibt Deacon nach einer neuerlichen Darlegung des Bjerknes'schen Zirkulationstheorems und

seiner Anwendung auf ozeanographische Probleme eine dynamische Aufarbeitung des ozeanographischen Beobachtungsmaterials der 106 "Discovery II"-Stationen der Zirkumpolarfahrt 1932—33, wobei in der Drake-Strasse und im Südantillenmeer 7 Stationen des "William Scoresby" von 1929 zur Ergänzung herangezogen wurden. Mit diesem dynamischen Material wird die dynamische Topographie der 0 und 600 Dezibar-Flächen relativ zur 3000 Dezibar-Fläche für das Antarktische Meer entworfen und in Karten zur Darstellung gebracht. Die Ausbeute aus diesen dynamischen Karten ist nicht sehr gross, und auch wenn noch andere für andere Niveaus gezeichnet worden wären, sie gleichen sich alle untereinander. Die Haupterscheinung ist der Abfall der Druckflächen von Norden nach Süden; die dynamischen Isobathen schliessen sich zumeist um den Antarktischen Kontinent, sie folgen nicht immer den Breitenkreisen und gelegentliche Abweichungen deuten auf nordwärts bezw. südwärts gerichtete Bewegungen, aber die zonale Komponente überwiegt doch weitaus und damit dieser entsprechend die zonalen, von Westen nach Osten gerichteten Bewegungen. Da die Analyse der Temperatur- und Salzgehaltsschnitte fast in jedem Profil eine Zirkulation mit meridionalen Geschwindigkeitskomponenten andeutet, ist es klar, dass die dynamische Verarbeitung des Beobachtungsmaterials nach der Bjerknes-Helland-Hansen'schen Methode diesen Beobachtungen nicht gerecht wird. Die Bedingungen des angewandten Theorems sind hier in der Nähe der Diskontinuitätsschichten der polaren Konvergenz usw. nicht als erfüllt anzusehen, sei es, dass ein stationäres Gleichgewicht nicht gegeben erscheint, sei es, dass die Reibungs- bezw. Mischungseinflüsse zu stark hervortreten. Deacon versagt sich daher vielleicht mit Recht eine weitere Diskussion des Problems, aber ohne Zweifel wird es dadurch erst recht interessant und erfordert eine weitere und tiefergehende Prüfung aller Faktoren, die für die schliessliche Gestaltung der ozeanischen Zirkulation von Einfluss sein können.

Nachtrag. Durch einen Zufall habe ich feststellen können, dass die in der zweiten oben besprochenen Arbeit von Deacon die dynamischen Tiefen, die für ein homogenes Meer von 0°C. und $\sigma = 28{\cdot}0$ berechnet sind, ab 2500 m. nicht richtig sind. Wahrscheinlich liegt ein Rechenfehler vor, der

Druck Dezibar	Anomalie der Dyn. Tiefe $D_{35‰,0,p} - D_{28,0,p}$	Werte nach Deacon	Unterschied 1—2	Druck Dezibar	Anomalie der Dyn. Tiefe $D_{35‰,0,p} - D_{28,0,p}$	Werte nach Deacon	Unterschied 1—2
0	0·0000	0·0000	+0·0000	400	0·0488	0·0472	+0·0016
10	0·0012	0·0011$_5$	+0·0000$_5$	600	730	708	+ 22
20	24	22	+ 2	800	972	940	+ 32
30	37	34	+ 3	1000	0·1212	0·1165	+ 47
40	49	47	+ 2	1500	1809	17(72)	+ (37)
50	61	58	+ 3	2000	2400	2351	+0·0049
60	73	71	+ 2	2500	2984	7962	—0·4978
80	0·0098	94	+ 4	3000	3563	8556	—0·4993
100	0·0122	118	+ 4	3500	4135	9153	—0·5018
150	183	175	+ 8	4000	4703	0·9739	—0·5036
200	244	235	+0·0009	4500	5266	1·0344	—0·5078
300	0·0366	0·0354	+0·0012	5000	0·5824	1·0963	—0·5139

die Werte um etwa 5 Einheiten der 1. Dezimale falsch macht. Ich habe in obenstehender Tabelle die Anomalien der dynamischen Tiefe $D_{28,0,p}$ gegenüber einem homogenen Meer von $35‰$ und 0°C. berechnet und

zwar nach den Tabellen von Sverdrup bis auf 6 Stellen genau. In der Tabelle sind die Werte nur bis auf 4 Stellen angegeben. Daneben stehen die Werte der Anomalie der dynamischen Tiefe nach Deacon und in der 3. Kolonne der Unterschied beider Werte. Bis 2000 m. ist der Unterschied klein und steigt allmählich bis 49 Einheiten der 4. Dezimale an; das liegt innerhalb der Abrundungsfehler. Aber ab 2500 m. sieht man sofort den Sprung in den Differenzen, die Werte von Deacon sind falsch. Ich halte mich für verpflichtet, hierauf aufmerksam zu machen, damit diese Werte nicht weiter verwendet werden.

A. Defant.

H. R. Seiwell. "The Minimum Oxygen Concentration in the Western Basin of the North Atlantic." Pap. in Phys. Oceanogr. and Meteor. Vol. V, No. 3, pp. 1—24, 8 figs. Cambridge, Mass., 1937.

Das Hauptsauerstoffminimum, seine Verteilung und seine Beziehungen zum Salzgehalt und zur Dichte werden auf Grund des umfangreichen Beobachtungsmaterials ("Atlantis", "Dana", "Meteor") im westlichen Nordatlantischen Ozean untersucht. Daran schliessen eine Betrachtung über die physikalische Bedeutung und zwei Theorien über die Entstehung des Hauptsauerstoffminimums.

Es wird darauf hingewiesen, dass bei einer Tiefenlage des O_2-Minimums von 800—900 m. im westlichen Nordatlantischen Ozean die üblichen vertikalen Beobachtungsabstände von 100 m. nicht ausreichen, Tiefe und Wert des Minimums genügend sicher zu erfassen. 35 m. Abstand zwischen den einzelnen Beobachtungstiefen werden als notwendig erachtet.

Die Salzgehaltsanomalien in der Tiefe des O_2-Minimums deuten in ihren negativen Werten im Süden auf eine Beimischung des salzarmen subantarktischen Zwischenwassers, im Osten in den positiven Werten auf eine Beimischung des salzreichen Mittelmeerwassers. Damit ist aber von Seiwell kein Beweis erbracht, dass die sauerstoffarme Schicht sich in der Ausbreitungsrichtung der beiden Wasserarten bewegt.

Eine enge Verknüpfung zwischen der Dichte und dem Sauerstoffminimum wird nachgewiesen. Mittels einer Reihenentwicklung wird das Minimum bei $\sigma_t = 27{\cdot}232 \pm 0{\cdot}008$ gefunden. Diese Übereinstimmung, deren zahlenmässiger Ausdruck auf die Tausendstel nur rechnerischen Wert hat, da die Fehlergrenze der Dichtebestimmung bei $\pm 0{\cdot}020$ liegt, trifft nur lokal für den westlichen Nordatlantischen Ozean zu. Bereits nördlich von Portorico im Konvergenzgebiet der subtroposphärischen nord- und südäquatorialen Wassermassen verschiebt sich diese Beziehung, indem das O_2-Minimum bei der Dichte $\sigma_t = 27{\cdot}34$ zu liegen kommt (s. G. Dietrich: "Über Herkunft und Bewegung des Golfstromwassers," 1937). Diese Tatsache schon deutet darauf, dass der Wert der Übereinstimmung zwischen Dichte und O_2-Minimum in der statistischen Beschreibung liegt, weniger aber in einer physikalischen Bedeutung zu suchen ist. Seiwell sieht in der Verknüpfung eine Erklärungsmöglichkeit des O_2-Minimums, indem er auf eine Ansammlung des absinkenden Detritus bei dieser Dichte $\sigma_t = 27{\cdot}232$ und damit auf einen verstärkten Sauerstoffverbrauch schliesst. Ein kausaler Zusammenhang der Anreicherung von Detritus mit dem vertikalen Dichtegradienten, nicht mit irgend einem Dichtewert, wäre verständlich.

In einer zweiten, chemisch-biologischen Hypothese wird das O_2-Minimum aus dem in der Vertikalen wechselnden Verhältnis Verbrauch:Zufuhr erklärt. An einem schematischen Beispiele zeigt Seiwell, dass ohne die Annahme der dynamischen Erklärung, nämlich verhältnismässig geringer

Bewegung in der sauerstoffarmen Schicht, das O_2-Minimum erklärt werden kann. Allerdings findet seine grundlegende Annahme, nämlich die vertikale Verteilung des O_2-Verbrauches, keine Erklärung. Da zur Zeit einwandfreie quantitative Verbrauchsvorstellungen des Sauerstoffs im offenen Ozean fehlen, bleibt diese rein chemisch-biologische Erklärung des O_2-Minimums im Stadium der Hypothese. Sie ist aber als ein wertvoller Beitrag zur Erklärungsmöglichkeit des O_2-Minimums von Seiten des Chemikers anzusehen. Zusammen mit einer inhaltlich verwandten Hypothese von H. Wattenberg (1937), die die Ausbildung des O_2-Minimums auf einen verstärkten Verbrauch des Sauerstoffs durch leicht oxydierbare C-Verbindungen unterhalb der Produktionsschicht zurückführt, wird die Diskussion gegenüber der bisherigen rein dynamischen Erklärung (G. Wüst, G. Dietrich) auf eine breitere Basis gestellt. So weit sich die Verhältnisse übersehen lassen, wird das Hauptsauerstoffminimum aus dem Zusammenwirken mehrerer Vorgänge dynamisch-chemisch-biologischer Art zu verstehen sein. Entscheidend ist nur, welches Gewicht den einzelnen Vorgängen beizumessen ist, nicht nur speziell für die Erklärung des Hauptsauerstoffminimums, sondern auch für die kleineren troposphärischen und stratosphärischen Minima, für die bereits dynamische Erklärungen vorliegen.

Günter Dietrich.

H. Pettersson. "Eddy-Viscosity in Stratified Water." Göteborgs Kungl. Vet.- och Vitt.-Samh. Handl. 5. Föl., Ser. B. Bd. 2, No. 1, pp. 21, 11 figs. Göteborg, 1931.

H. Pettersson and H. W. Malmheden. "Eddy-Viscosity in Stratified Water II." Göteborgs Kungl. Vet.- och Vitt.-Samh. Handl. 5. Föl., Ser. B, Bd. 4, No. 8, pp. 14, 4 figs. Göteborg, 1935.

The first paper contains a description of some experiments carried out in order to obtain information on how stratification of the sea water affects turbulence and the coefficient of virtual friction.

The author has repeated an experiment made by V. W. Ekman in 1906 (Ann. d. Hydr. XXXIV, 1906 p. 23). A cylindrical glass vessel, filled in one case with stratified, in another case with homogeneous water of the same mean density is rotated at a uniform velocity round a vertical axis, a light aluminium vane, pivoted at the axis, indicating how the rotation is transmitted upwards. The rate of transmission was found to be considerably greater with homogeneous than with stratified water, as well as the corresponding values of the coefficient of friction, μ, calculated by Ekman from his observations.

The measurements of Ekman are repeated and completed. Moreover, the author studies in detail the movement of the water particles and finds that there is a vertical circulation, due to centrifugal forces, with an outflow at the bottom from the centre to the wall of the cylinder. In the case of homogeneous water this circulation extends through the whole column; in the case of stratified water it is limited to the undermost layer. Thus the author's result is that turbulence has probably very little to do with the increase of μ when the water in the rotating vessel is changed from a stratified to a homogeneous state. An experiment of this kind therefore does not give information about the question of the manner in which virtual friction is influenced by a density gradient.

In order to eliminate the complication of the vertical circulation the authors of the second paper have modified the experimental arrangement described above.

Within the cylindrical glass vessel (36 cm. wide) another cylinder of smaller diameter is placed co-axial with the outer cylinder, so that there is an interspace about 4 cm. wide. This space is filled with water, to the surface of which a velocity can be imparted by a smooth metal ring, rotating round a vertical axis, coincident with that of the cylinders. As in the former experiment, the rotatory movement of the ring will produce a vertical circulation in the water. In stratified water, however, this circulation is limited to the uppermost layer only. Therefore the authors used a top layer of tap water, some 2 cm. thick, in the surface of which the ring moved.

The downward spread of the rotatory movement was studied in homogeneous as well as in stratified water. The velocity of the water movement was measured with the help of small spherical glass bulbs, floating in the water and balanced so as to remain at desired levels. As the ring goes on rotating, a stationary state will soon be established. The observations hitherto carried out prove that the diminishing effect on virtual friction due to a strong density gradient at a boundary surface is particularly conspicuous in the initial stage, when the velocities at the lower levels are still increasing.

The paper is published as a preliminary report, the mathematical analysis of the results being reserved for a subsequent publication.

S. E. S.

K. Suda. "On the Dissipation of Energy in the Density Currents. 2nd paper." Geophys. Mag. Vol. X, No. 2, S. 131—243, 50 figs. Tokyo, 1936.

Diese Arbeit ist eine verbesserte Fortführung einer an derselben Stelle 1932 erschienenen (s. Journ. du Cons., 1933, S. 263); sie stützt sich nicht nur, wie der Verf. sagt, auf eine weit grössere Anzahl neuerer (und, wie Wüst zeigte, besserer) Beobachtungen, sondern sie behandelt die Aufgabe selbst umfassender. Den Ausgang bildet wiederum die Berechnung des Stroms nach Bjerknes, Sandström und Helland-Hansen auf Grund der Verteilung des Salzgehalts und der Temperatur; die Berechtigung hierzu folgert der Verfasser daraus, dass der Wind nur einen nebensächlichen Einfluss habe, weil selbst der Übergang vom Sommer- zum Wintermonsun keine grundsätzliche Änderungen im Strombilde hervorruft; Beobachtungen mit dem Ekman-Merz-Strommesser (freilich vom treibenden Schiffe aus) bestätigen im allgemeinen die Stromberechnungen.

Sehr viel schwieriger ist der Koeffizient der turbulenten Reibung (Austauschzahl) zu ermitteln, dem das erste Kapitel der Arbeit gilt. Mangel an Strombeobachtungen zwingt dazu, von dem Vordringen der oberflächlichen Erwärmung des Wassers in die Tiefe auszugehen, wobei vorbehalten bleiben muss, die Austauschzahl der Wärme später durch die der Bewegung zu ersetzen, was möglicherweise nur auf das Hinzufügen eines Proportionalitätsfaktors hinauskommen würde. Trotz aller Schwierigkeiten kann es der Verfasser unternehmen, eine Karte für die Verteilung der Scheinreibung in 25—50 m. Tiefe zu zeichnen, der er eine andere für die Richardson'sche Zahl zur Seite stellt. Das zweite und Hauptkapitel behandelt unter Beigabe zahlreicher Karten die Strömungen in den japanischen Gewässern selbst und den Energieverlust in ihnen an der Oberfläche und in der Tiefe zu verschiedenen Jahreszeiten, der sich im Kuroschio und an der Polarfront im Japanischen Meere auf mehr als 100 erg./sec. im cbm. steigert. Zwischen dem Kuroschio und dem, wie die Untersuchung zeigt, zum grossen Teile aus dem Ochotsker Meere gespeisten Oyaschio entwickelt sich ein breites Mischgebiet,

in dem sich Kuroschiowasser als dünne Oberflächenschicht ausbreitet. Der Energieverlust im Oyaschio beträgt nur etwa $^1/_5$ von demjenigen im Kuroschio, und daher ist zu seiner Aufrechterhaltung auch nur $^1/_5$ so viel Energiezufuhr nötig. Im Japanischen Meere ist die schnelle Zunahme des Energieverlustes während des Sommers bemerkenswert. In den tieferen Schichten nimmt überall der Energieverlust sehr stark ab, woraus hervorgeht, dass die Tiefenströmungen zu ihrem Bestehen nur wenig Energieersatz benötigen. Das dritte Kapitel beschäftigt sich zunächst mathematisch mit der Umformung der Energie, um zu einer Abschätzung der Energiequellen für die Strömungen in den japanischen Gewässern zu gelangen und Anhaltspunkte für die Beurteilung von Änderungen der Ströme zu gewinnen.

Es liegt in der Natur der Sache, dass bei unserer noch recht unsicheren Kenntnis der Turbulenz im Meere jede Berechnung von Energieverlusten vorläufig eine allererste Abschätzung bleiben muss. Mag aber auch vielleicht künftige Forschung die in der vorliegenden Arbeit gegebenen Zahlenwerte merklich ändern, so darf man doch annehmen, dass die Grundzüge der Verteilung des Energieverlustes, wie sie auf den zahlreichen Karten zu Tage treten, und wie sie sich grundsätzlich wiederholen, ein Abbild der Naturvorgänge darstellen.

H. Thorade.

K. Suda. "On the Method of the Practical Study of the Variations of the Oceanographical State of the Ocean and the Sea." Geophys. Mag. Vol. XI, No. 1, S. 75—90, 6 figs. Tokyo, 1937.

Um die zeitlichen und örtlichen Schwankungen von Temperatur, Salzgehalt, Dichte, Stromgeschwindigkeit usw. möglichst deutlich zu veranschaulichen, schlägt der Verf. Karten oder Schnitte mit Linien gleicher relativer Änderung ("Variabilität") der fraglichen Grösse vor. Solche Linien können aus den gewöhnlichen Isothermen, Isohalinen usw. nach Bjerknes durch graphische Methoden abgeleitet werden. Sie lassen die Gebiete grösster Variabilität erkennen, wie ein Beispiel von 5 Schnitten durch den Kuroschio südlich von Siwono Misaki für Sommer und Winter zeigt: Einem Maximum von jahreszeitlichen Schwankungen an der Oberfläche, das sich durch Turbulenz nach unten fortpflanzt, stehen in der Tiefe zwei Kerne gegenüber, die dem Kuroschio und dem Gegenstrom entsprechen, und in denen die Schwankung in der Stärke des Wassertransportes begründet ist. Die Schwankung der kinetischen Energie dagegen ist gering.

H. Thorade.

J. Proudman, H. M. Lewis and A. L. Dennis. "On the Temperature of the Surface Waters of the Irish Sea." Phil. Trans. Roy. Soc. London, Ser. A — Math. & Phys. Sci., Vol. 236, No. 765, pp. 261—302, 6 figs. London, 1937.

The authors here make use of all available observations of the surface temperature of the Irish Sea from the years between 1900 and 1934. The major part of these observations is unpublished.

Earlier work on the Irish Sea has been done by Dickson, Johnstone, Matthews, Daniel, Farran and Spicer.

The observations originate from 105 fixed stations in the Irish Sea and have been recorded by the Marine Biological Station at Port Erin Bay, lightvessels, research and patrol vessels and liners, but records have been kept throughout the entire period 1903—1931 only at Port Erin Bay and the "Seven Stones" L. V.

Grand monthly means are calculated for each of the stations and given in a table. It is obvious that the grand monthly means for the various stations are not directly comparable, as they refer to periods of various lengths, from 3 to 29 years. The authors therefore calculate the deviation of the particular monthly mean from the grand monthly mean for each station and for each possible month. The monthly anomalies of each station are then correlated with the simultaneous anomalies at Port Erin Bay. Tables showing the correlation coefficients and the monthly anomalies at Port Erin Bay are given.

On the basis of the correlation between the temperature anomalies at Port Erin Bay and at a given station the grand monthly means at the station 1903—1931 are then calculated for the entire period by means of the equation:—

$$m = m' - r \cdot \frac{\sigma}{\sigma_0} \cdot a_0$$

m denotes the calculated grand monthly mean for the entire period, m' the observed grand monthly mean for the partial period, r the correlation coefficient, σ and σ_0 the standard deviations of all observations at the two stations, and a_0 the mean value of the monthly anomalies at Port Erin Bay during the common period of observations.

Grand mean values of temperature inferred for the period 1903—1931 for each month at 28 stations and for the months February, May, August and November at 39 stations, and for the year at all 28—39 stations. These values were used for constructing 5 charts giving the grand mean isothermal lines for the months of February, May, August and November and for the year.

In addition, the correlations between sea-water temperature and air temperature, barometric gradient, sunshine duration, cloud amount, relative humidity, evaporation and rainfall are studied.

All scientists interested in the hydrography of the Irish Sea will greatly appreciate this work, in which the authors have succeeded, in spite of somewhat scattered data, in giving an excellent account of the temperature conditions of the Irish Sea over a long period. The fact that the surface temperature of the Irish Sea is to a high degree representative of the temperature of the deep water gives this work further significance.

Helge Thomsen.

N. W. Rakestraw. "The Occurrence and Significance of Nitrite in the Sea." Biol. Bull., Vol. LXXI, No. 1, pp. 133—167, 12 figs. Woods Hole, Mass., 1936.

In the effort to explain the production and utilization of nitrite and its place in the nitrogen cycle of the sea, Rakestraw has collected over a period of five years nitrite data from inshore stations in shallow bays, from stations on the continental shelf, to the south of Cape Cod, Mass., from a number of stations in the Gulf of Maine, from deep sea stations in the area worked by the "Atlantis", from bottom muds and waters, as well as from water samples stored under a variety of conditions. Analyses were carried out by means of the Griess-Ilosvay method according to Buch.

The records indicate a variation in the nitrite concentration of sea water normally from 0 to ·35 microgramme atoms per litre. Only occasionally values up to double this amount were encountered.

Seasonal changes in the Gulf of Maine were found to be similar to those

recorded by Soot-Ryen from a Norwegian fjord, and Verjbinskaya's data from the Barents Sea and Cooper's very complete study from the English Channel were found to accord with these: A minimum in January and February, especially at the surface, corresponding to the period of maximum nitrate and phosphate, a slow increase in nitrite until April. Simultaneously with the increase in the diatom population, the nitrite starts to disappear. The maximum of nitrite occurs between June and September. The utilization of nitrite in the surface layers, simultaneously with its production throughout a much deeper water mass, results in the appearance of a maximum zone, generally between 30 and 50 metres.

Four observations from deep sea stations in truly oceanic conditions indicate quite different seasonal changes, which are still incompletely studied.

The distribution of nitrite is compared with that of nitrate and phosphate, representing the nutrient salts, with temperature and density distribution and, as far as the scanty determinations allow, with that of ammonia.

About 300 samples were stored without special precautions, exposed to "probably less than normal illumination." The predominating tendency under these conditions was found to be for nitrite, if initially present, to disappear on standing. If initially absent, it may appear in small amounts. Some more carefully controlled experiments, with and without sterilization in an autoclave, with and without light, brought out that the samples stored in darkness showed no significant change in nitrite. Those kept in the light, after 19 days, reached the same value, either by increase or decrease. This interesting result is now the subject of further investigation.

The general conclusion drawn from the data obtained on the nitrite content of "bottom water," interstitial bottom water and supernatant bottom water, was that the decomposition of organic matter at the sea bottom involves oxidation of nitrogen compounds to nitrite and nitrate, and that this process is much more intense on shallow bottoms than deep. Nearly all of the nitrification must have taken place before organic matter reached the bottom in the latter cases.

Mud samples were analysed again after having stood for one day. The results indicate that nitrite was formed rapidly and continuously in the mud, diffusing into the water in contact with it. In the water, however, the nitrite was rapidly destroyed by oxidation to nitrate.

After discussing the literature on the various possibilities of the position of nitrite in the nitrogen cycle in the sea, Rakestraw evaluates his own results on this problem and finds that they are best explained on the assumption of oxidation of ammonia to nitrite. The correspondence of the intermediate maximum zone of both nitrite and ammonia supports this view.

During winter decomposition of organic matter goes on very slowly and takes place largely at the surface. In late winter and early spring, as the unstable column becomes deeper, these processes take place through a deeper vertical range. When diatoms begin to grow actively they use the nitrite in the surface water, along with nitrate, and occasionally, when there are plenty of other nutrients, nitrite is not exhausted. Since organic matter works its way downward by settling, diffusion, and mixing, the appearance of nitrite by oxidation extends below the zone of its utilization. At greater depths it disappears again by further oxidation to nitrate. Nitrification seems, however, to extend further than the occurrence of nitrite would indicate, the formation of nitrite presumably being associated with the first stages of decomposition, and the whole process of nitrification not being completed until greater depths are reached.

Rakestraw's clear paper gives a lot of new information on nitrite

distribution in the sea. It will form a good background for the bacteriological studies of the nitrogen metabolism in the sea, which are also included in the programme of work at the Woods Hole Oceanographic Institution. We are eagerly looking forward to the results of further investigations now in progress.

T. B.

R. J. Robinson and H. J. Spoor. "Photometric Determination of Silicate in Sea Water." Industr. and Engin. Chem. (Anal. Edit.) Vol. 8, pp. 455—461. Easton, Pa., 1936.

The authors have examined the determination of silicate in sea water using the Zeiss Pulfrich photometer with the violet S43 filter. They find that the maximum development of colour occurs between pH 1·5 and 2·3 in agreement with Atkins, pH 2. The maximum is reached within three minutes and persists for at least two hours. For a number of reasons they prefer a buffered solution of potassium chromate to picric acid as colour standard (but see Wattenberg, Rapp. et Proc.-Verb. Internat. Cons. p. l'Expl. de la Mer, 1937, Vol. CIII, p. 16.). Beer's law applies only approximately. In sea water they state that, due to salt error, determinations must be multiplied by 1·16 to give the true value. Wattenberg (loc. cit.) has suggested that this figure is in error and that the author's own data yield a factor, 1·25, for $29^0/_{00}$ salinity. To the reviewer their factor appears to be even higher, about 1·30. These values agree well with Wattenberg and Meyer's figure, 1·28 for the same salinity (Wattenberg, l.c.), but are still much lower than that of Brujewicz and Blinov, 1·66.

L. H. N. C.

N. W. Rakestraw, H. E. Mahncke and E. F. Beach. "Determination of Iron in Sea Water." Industr. and Engin. Chem. (Anal. Edit.), Vol. 8, pp. 136—138. Easton, Pa., 1936.

The amount of iron and the form in which it exists in sea water is of much importance for the growth of phytoplankton, and recently the subject has received attention in several laboratories. The authors of this paper have devised a useful method of concentration and determination. By means of alkaline sulphide, the iron is co-precipitated with magnesium hydroxide; the precipitate is dissolved in acid, oxidized with bromine water, the iron reprecipitated as hydroxide and finally determined with thiocyanate. An important advance in technique is the stabilization of the resulting coloured compound in aqueous solution by ethylene glycol monobutyl ether. The method gives reproducible results and fluoride does not interfere.

Elsewhere the reviewer has suggested that true ionic iron (Fe^{+++}, $FeOH^{++}$ and Fe^{++}) is unlikely to exceed about 10^{-7} mg./m^3. in natural sea water and so he cannot agree with the authors that their method determines "free dissolved ferrous and ferric ions." In water from the western North Atlantic passed through a Seitz filter, iron seldom exceeded 10 mg. per cubic metre. Often none was found. This iron may have been present as highly dispersed inorganic or organic colloids or as organic compounds in true solution. In agreement with other workers, they found considerably more iron in unfiltered water. In all papers so far published, soluble iron has been defined as that iron fraction which will pass an arbitrarily chosen filter, and the problem of separating "insoluble" from "soluble" iron has not yet been solved. Most likely there is no soluble iron to separate.

L. H. N. C.

C. L. Utterback and W. Jorgensen. "Scattering of Daylight in the Sea." Journ. Opt. Soc. America, Vol. XXVI, No. 6, pp. 257 to 259, 2 figs. Philadelphia, 1936.

The authors describe measurements on the downward and upward illumination at different depths down to 30 m. below a smooth water surface under a cloudless sky as made with a rectifier cell (almost certainly a Weston "Photronic") mounted in a watertight case behind blue, green, and red filters, respectively, the series with the photometer window turned first down and then up being made consecutively and as rapidly as possible. The water was not very clear, the average extinction coefficients for blue, green, and red being 0·195, 0·18, and 0·33 respectively. The ratio of the upward to the downward illumination only varied slightly with depth for the blue and green, being near 0·02 for blue and from 0·01 to 0·015 for green. For red, however, the ratio increased from about 0·002 near the surface to about 0·02 at 20 m.

The authors suggest that the rise in the ratio for the red is partly due to the increasing abundance with depth of organisms which reflect red light, and partly to the effect of differential absorption in the spectral band transmitted by the red filter. Absorption increases very rapidly with wavelength in the neighbourhood of 600 mμ., and near the surface much of the radiation affecting the upward-turned photometer would be absorbed so rapidly that only a very small percentage could be scattered back on to the window when the latter was inverted. At lower levels only the more penetrating short-wave end of the spectral band would be appreciable, so that the depth of the layer of water below the photometer scattering light back on to it would be considerably increased. It is worth noting that the extinction coefficient for downward-passing red light fell from 0·48 between 0·15 and 5 m. to 0·23 between 20 and 25 m.

The fact that blue shows both a higher extinction coefficient and greater back-scattering than green suggests that the increased opacity in this part of the spectrum is largely due to increased scattering rather than to absorption. This is in accordance with other evidence, such as the high transparency of true oceanic water to blue.

The authors' values for the percentages of back-scattered light for all colours are rather lower than those found by Clarke. It is just possible that this difference may be due to the omission of a diffusing window, which is not mentioned, as a clear-glass window will totally reflect any light making a larger angle than 48·6° with the normal, and might therefore be expected to show lower relative sensitivity to scattered light.

The results are of great interest and it is to be hoped that they will be extended by further work.

H. H. P.

W. M. Powell and G. L. Clarke. "The Reflection and Absorption of Daylight at the Surface of the Ocean." Journ. Opt. Soc. America, Vol. XXVI, No. 3, pp. 111 to 120, 4 figs. Philadelphia, 1936.

The measurement of the fraction of the incident daylight which is cut off by the surface of the ocean presents certain difficulties, and the investigations described in this paper are of interest to all workers in the subject. Unless the surface is very smooth the illumination just below it varies rapidly and irregularly, and it is hard to maintain a photometer at even an approximately constant small depth of immersion. Under these

conditions the potentiometer method of current measurement, which works excellently in the steadier light at greater depths, is unsuitable, and the authors' thyratron integrating circuit has much to recommend it for work with emission cells, as used in their earlier experiments. When using rectifier cells yielding only small E. M. F.s they found a suitably damped galvanometer satisfactory. It is also necessary to guard against errors arising from differences in the shading caused by the ship's hull just above and just below the surface, respectively, and to make correct allowance for the alteration in the reflection loss at the upper surface of the diffusing glass of the photometer caused by immersion in water.

Surface losses are generally estimated by extrapolating the extinction curve found from deeper readings back to the surface. The authors, in common with other workers, find that when this is done the percentage loss for very smooth water may be very small, agreeing within the limits of error with that calculated from the Fresnel reflection formula. With rough water, however, the loss may run up to 30 per cent., or more, and the authors have compared these large losses with measurements of the light reflected from the surface, as measured by an inverted photometer suspended a few metres above it. They used both red-sensitive and violet-sensitive emission cells suspended from a floating tubular structure designed to cast very little shade. They also measured the light scattered back by matter beneath the surface by lowering the inverted photometer until it was just submerged. They found that the reflected light reached a minimum, about 3 per cent. for red and 4 per cent. for violet, on clear days with high sun and smooth water. The percentages rose with decline in solar altitude, the red, as is natural, being most affected, or with cloudy conditions, and they were also raised by roughness of the water surface, but only with a combination of comparatively low sun and disturbed water did they exceed 10 per cent., so that the authors conclude that surface reflection and sub-surface back-scattering are not the sole causes of the surface loss in rough weather. This they attribute largely to the formation of an extinguishing layer often about 1 m. deep. Some of their measurements show a discontinuity in the extinction coefficient for vertical submarine illumination, the coefficient being much higher within 1 m. of a rough surface. Some of these, and their later reflection measurements were made with "Photox" rectifier cells whose maximum sensitivity is in the green.

They consider that this extinguishing layer is certainly due to bubbles of air formed and carried down by breaking wave-tops. Such bubbles can actually be seen under water in suitable circumstances.

At first sight it seems a little strange that the radiation which is stopped by the bubbles does not make its appearance at the surface, as there seems to be little reason to expect genuine absorption. When, however, we consider the refraction and reflection of light by a bubble large compared with the wave length we find that over 50% is deviated through angles between 20° and 60°, only about 1% being deflected through more than 90°. Thus the chief action of such bubbles should be to increase the average obliquity and thus the optical path through the water for a given depth. The rough water surface would of course itself contribute to this effect. We should, however, expect the enhanced obliquity, and consequent increased extinction coefficient, to extend to greater depths, which is not in accordance with the authors' results. They have made some determinations of the ratio of horizontal to vertical illumination at different depths, but as they apparently worked at a distance of some metres from the ship's side (instead of at the bow or stern) it is hard to avoid the suspicion that shading by the hull may

have been of importance, and further work on the subject of obliquity would seem to be desirable.

H. H. P.

G. L. Clarke. "On the Depth at which Fish can see." Ecology, Vol. XVII, No. 3, pp. 452—456. Brooklyn, 1936.

By combining Grundfest's measurements of the sensitivity of the eyes of the sun fish, *Lepomis*, to very weak monochromatic illumination of different wave-lengths with measurements of submarine illumination at various depths, the author has given an estimate of the greatest depth at which a fish with eyes similar to those of *Lepomis* would be able to see. Grundfest found that *Lepomis*, after two hours in darkness, would just respond to the motion of a screen of alternate bars and spaces covering a field of brightness about 10^{-6} millilambert and of wave-length about 540 mμ. For longer or shorter waves the sensitivity fell rapidly. This brightness corresponds to about 10^{-10} of full daylight, an intensity which, according to the author's and other workers' measurements, would be reached at depths ranging from 28 m. in Adelaide Lake, Wisconsin, to 430 m. in the Sargasso Sea. In all the lakes and coastal waters considered the range of vision exceeded the depth of water. In the Sargasso Sea it only amounted to some 10 per cent. of the depth.

The maximum spectral sensitivity of *Lepomis* occurs close to the region of maximum transmission for coastal sea waters. In oceanic water the maximum transmission occurs at shorter wave-lengths, and in many lakes at longer wave-lengths. It is interesting to note that the sensitivity of *Lepomis* seems to be less than that of the human eye for wave-lengths below 600 mμ., and greater than it above that limit, so that its motions could no longer be followed. Also, its maximum sensitivity occurs at a rather longer wave-length than that of the dark-adapted human eye. This is interesting in view of the fact that it inhabits fresh water, and the author suggests that it would not be unreasonable to suppose that the maximum sensitivity for deep-sea fish might be considerably shifted towards the blue.

It seems probable that the sensitivity for such deep-sea fish would greatly exceed that for the human eye, and therefore that of *Lepomis*, but the effect on the limits of vision would not be very large, since an increase of 100 times in the sensitivity would only increase the depth limit by some 20 per cent.

H. H. P.

M. M. Ellis. "Detection and Measurement of Stream Pollution." U. S. Dep. Comm., Bureau of Fish., Bull. No. 22, pp. 365—437, 22 figs. Washington, 1937.

The study of river pollution is an urgent necessity for all densely populated countries and all workers on the subject will find this paper invaluable. Dr. Ellis is in charge of the Interior Fisheries Investigations of the U. S. Bureau of Fisheries and has drawn on his own very wide experience and the abundant records obtained by the Bureau to produce what may be properly called a monograph on the subject of pollution and fisheries.

The author first considers the effect of polluting matters on aquatic environments. In order to estimate the limiting concentrations for fish of various constituents of river waters which may be altered by pollution, e.g., oxygen, ammonia, pH, etc., he uses a statistical method which appears to

be new. He takes all the analytical figures for each constituent, regardless of the actual amount present, from all localities where a good mixed fish fauna was present and from them constructs frequency diagrams showing in what percentage of cases a good fish fauna was present at a given value of the constituent under consideration. To take an example, he finds that during the warm season, in 96 per cent. of the good fish stations the dissolved oxygen concentration was 5 parts per million or more and no good fish fauna was found where the oxygen concentration was below 4 parts per million. From this he concludes that 5 parts per million is the lower limit of oxygen if the waters are to support a normal population of fish. He rightly emphasizes that this value is not the asphyxial limit; from experiments carried out in the laboratory, it appears to be the point at which the fish has to make compensatory adjustments to oxygen lack. Most people will agree, however, that a figure of this kind, derived from observations in nature, where the fish are free, within very wide limits, to choose their own environment, is a better measure of their requirements than can be obtained by laboratory experiments. This method gives excellent results, and statistics of this kind would be well worth collecting in other countries.

The importance of carbon dioxide in freshwater biology appears to have been almost entirely overlooked. The relation between carbonates, bicarbonates, carbon dioxide and pH is not discussed at all, although it is essential to an understanding of the effect of many substances on the aquatic environment. Nor is the very general inverse relation between the oxygen and carbon dioxide contents of waters polluted by organic effluents mentioned and although on page 389 a discussion of the toxicity of carbon dioxide is promised, it is found nowhere in the paper. The reviewer must confess to considerable disappointment with this portion of the work, for he is convinced that this substance is of the utmost importance, especially when the effect of acid wastes on hard-water streams is under consideration.

There follows a short but extremely valuable section on the action of various polluting materials on the fish themselves. A distinction is drawn between those substances which injure the gills or other external structures and those which enter the body of the fish and exert true toxic action. This part contains many new facts essential to the proper understanding of the toxicology of fishes.

Then there is an account of the lethality of numerous substances found in polluting effluents as determined by the use of the goldfish, *Carassius auratus*, and the cladoceran, *Daphnia magna*, as test animals. This work has been carefully done and the importance of the nature of the water with which the poisons are diluted is emphazised, a feature which adds greatly to the value of the tables. It is probable that the neglect of this factor is mainly responsible for the very wide discrepancies between the results of other workers in this field.

Finally there is a list, compiled partly from the author's own experiments and partly from a wide reading of the very scattered literature on the subject, of the lethal limits of no less than 114 substances likely to be found in polluting effluents. It is very useful to have this information assembled and many will be grateful to Dr. Ellis for it.

F. T. K. P.

E. Steemann Nielsen. "The Annual Amount of Organic Matter produced by the Phytoplankton in the Sound off Helsingör." Medd. Komm. Danmarks Fisk.- og Havunders., Ser. Plankton, Bd. III, Nr. 3, pp. 1—37, 6 figs. Köbenhavn, 1937.

From October 1932 to September 1933 Steemann Nielsen carried out assimilation experiments according to the method introduced by Gaarder and Gran, at a station in the Sound. The aim was to obtain a measure of the amount of organic matter produced by the phytoplankton in this part of the sea. The poverty of the phytoplankton population during January and February hindered the experiments at this time of the year. The experiments were duplicated and the oxygen determinations carried out with special care, three parallel analyses being made of each sample. Temperature and salinity, as well as quantities of nannoplankton, were recorded for each excursion. On account of the currents in the Sound, both the hydrographical conditions and the plankton conditions changed considerably from time to time, sometimes the Baltic influence being most strongly noticeable, and Kattegat water being prevalent at the surface at others. In the first case the phytoplankton consisted mainly of small flagellates, while in the latter diatoms played an important role.

On the basis of metabolism values for surface experiments and an assumed depth of the productive layer of 4 m., the author estimates the annual production of organic matter per m^2. of the surface at this locality in the Sound, 1932—33, at 130 grammes glucose, and the surplus of organic matter produced by the phytoplankton at 110 grammes. These values give, at least, the order of size of the production. In the north-western part of the Kattegat at Frederikshavn, the author previously estimated the *monthly* production in summer to be 150 grammes or nearly 1½ times as great as the *annual* production in the Sound.

In his discussion of the variation in the phytoplankton population, the author stresses the importance of weather and transparency conditions for the growth of the population. The Sound water is very poor in phytoplankton until the middle of March, while in the Kattegat the production has then been going on rapidly for nearly two months. The main causes of this late increase in the population in the Sound were assumed to be the low transparency and the high degree of turbulence as compared with the Kattegat waters.

In connexion with the metabolism experiments the author had intended to carry out laboratory experiments on the photosynthesis in various conditions of light, all the year round. This plan could for various practical reasons not be carried through, except for the October experiments. These gave as a result that the assimilation reached its optimum at a light intensity of 6,000 to 7,000 lux. At 1,500 lux the assimilation was found to be half the optimal intensity.

Metabolism experiments are necessary to give data about the actual production of organic matter. The present paper shows how they can be carried out with success even when conditions actually are not favourable for such studies. Comparative regional investigations along these lines would undoubtedly yield interesting results. The quantitative phytoplankton data from the Sound give another example of the outstanding importance in coastal regions of transparency and turbulence of the waters and of weather conditions for variations in the phytoplankton population.

T. B.

T. J. Hart. "*Rhizosolenia curvata* Zacharias, an Indicator Species in the Southern Ocean." Discovery Rep., Vol. XVI, pp. 413—446, 7 figs., 1 plate. Cambridge, 1937.

Die genannte Art (Syn. *R. curvata* Karsten) hat im Gegensatz zu den meisten Diatomeen ihres Gebietes eine beschränkte Verbreitung. Sie ist in der subantarktischen Zone, d.h. zwischen der antarktischen und der subtropischen Konvergenz beheimatet. Sie überschreitet aber oft die antarktische Konvergenz und kann jenseits (d.h. meist südlich) davon als Leitform für das Vordringen subantarktischen Wassers dienen. Um das nachzuweisen wurden ausser früheren Funden ("Valdivia", "Scotia") zahlreiche "Discovery"-Fänge benutzt, die rund um den antarktischen Kontinent ausgeführt wurden, Vertikalfänge von 100—0 m. mit dem Gran'schen Netz. Die Häufigkeit in den Fängen wurde nach der Hensen'schen Zählmethode festgestellt. Das Nichtvorkommen südlich der Fundstellen wurde sorgfältig geprüft. Ferner wurden Messungen des Querdurchmessers der Zellen angestellt. Häufigkeit und Grössenmasse wurden hauptsächlich zur Temperatur des Wassers und zu den Abständen von der antarktischen Konvergenz in Beziehung gesetzt. Es werden nacheinander besprochen die Scotiasee und das Südgeorgiengebiet, der östliche Südatlantische Ozean, der Südindische Ozean und das Meer im Süden von Australien, das Tasmanische Meer und der südliche Stille Ozean. Besonders eingehend wird der Meridian 80°W.L. untersucht und dabei auch der Unterschied der jeweiligen wirklichen Lage der antarktischen Konvergenz zur Fangzeit gegenüber ihrer mittleren Lage erfolgreich berücksichtigt. Auf die Beheimatung der Art in der subantarktischen Zone deutet ausser der Häufigkeit auch der Umstand hin, dass nur dort Auxosporenbildung stattfindet, jenseits der Konvergenz nur Fortpflanzung durch Teilung. Nordwärts von der antarktischen Konvergenz geht die Art nicht weiter als 300 Sm., was ungefähr der Temperaturgrenze von 8·5°C. entspricht. Ihre grösste Häufigkeit erreicht sie in den südlichen Teilen der subantarktischen Zone. Sie gehört dort einer "solenoiden" Gemeinschaft (*Rhizosolenia*-Plankton) an, während sie südlich davon in eine andere Diatomeengemeinschaft eintritt. Die Zellengrösse steigt im allgemeinen mit der Temperatur, wird aber bei den höchsten Temperaturen wieder deutlich geringer. Häufigkeit und Zellengrösse von *Rh. curvata* haben eine typische Jahresperiode. Das Überschreiten der Antarktischen Konvergenz durch die Art, was sie zu einer Leitform für das dortige Mischwasser macht, hat zur Ursache einerseits lokale Windtriften in der warmen Jahreszeit, andererseits südwärts gerichtete Strömungen, die durch Absinken kalten Wassers weiter südlich hervorgerufen werden. Dass die Art sich in der subantarktischen Zone dauernd zu halten vermag, erklärt sich vielleicht aus einer Unterströmung, welche von dem Absinkgebiet in etwa 45°S.Br. südwärts bis dicht an die antarktische Konvergenz vordringt.

E. H.

H. E. Bargmann. "The Reproductive System of *Euphausia superba*." Discovery Rep. Vol. XIV, pp. 325—350, 26 figs., plates I—V. Cambridge, 1937.

This is an introduction to a further paper on the development and distribution of post-larval and adult krill. It contains a detailed and exact account of both male and female reproductive organs at all stages and entailed an examination of over 5,000 specimens, all of which were measured and dissected and the degrees of development of external and internal genitalia noted. The results show that this labour was most certainly

worth while, interesting and valuable facts relative to the growth of the reproductive organs in this extremely important euphausian being brought to light. Both male and female gonads are developed before any external sexual characters appear; therefore the sex at an early stage can only be ascertained by dissection, which shows that the sex may be recognized in specimens as small as 18·20 mm. in length. The second pair of pleopods in the male are far behind the first in development, the first pair showing sexual modification before any differentiation of the second pair has begun.

The author has determined that fertilization must be external. In all the specimens examined the sperm was always confined to the thelycum and there was no sign of penetration into the body. Transference of spermatophores occurs in the first place before the female is gravid and the spermatozoa retain their potency for some time.

As many as 11,230 and 11,407 eggs were counted in the ovaries of two females and in spite of the large number of eggs the process of egg-laying is a rapid one, and it is probable that it takes place at a depth of 200 metres or more.

The paper is well illustrated by good black-and-white drawings and photographs of sections, besides a coloured figure of the adult male and female.

M. V. L.

R. Gurney. "Larvae of Decapod Crustacea. Part IV. *Hippolytidae.*" Discovery Rep. Vol. XIV, pp. 351—404, 137 figs. Cambridge, 1937.

The fourth part of Dr. Gurney's account of the decapod larvae obtained by the "Discovery" Expedition fulfils the promise of the previous parts and is equally suggestive. The family Hippolytidae consists of a large number of genera whose larvae are only known in a few species, but what is known shows them to be varied in form although agreeing in certain essential features. This is the first time that the larvae have been brought together as a whole, and a summary of the characters of eight genera is given. It has been found exceedingly helpful to bring into this report certain material from other collections, and the author's own work on the larvae from Ghardaqa in the Red Sea as well as larvae from the Great Barrier Reef Expeditions have increased the value of the work to a large extent, for it enables comparisons to be made which otherwise would have been impossible. This is the only really useful way of dealing with larvae from large expeditions. It is here shown that Bate's remarkable genus *Eretmocaris* is composed of several genera. Twelve forms are described, eight of which probably belong to *Lysmata*, two more probably closely related, and finally two which perhaps do not belong to the Hippolytidae at all, although having the very much elongated eye-stalks. Next comes *Tozeuma, T. carotinense* being obtained from the egg, thus establishing the type of larva previously only determined by supposition. Two further species from the Barrier Reef show the enormously elongated rostrum. One of these is almost certainly the same which was figured by Kemp (1910) and which is probably *T. armatum*. *Chorismus antarcticus* from the neighbourhood of South Georgia is peculiarly interesting in its abbreviated development, and in *Saron marmoratus* and certain allied forms we have a group of closely related Hippolytids which are apparently allied to *Latreutes*.

The clear outline drawings throughout the monograph add much to its value. The whole report is a real help towards the identification of decapod larvae.

M. V. L.

J. L. Fuller and G. L. Clarke. "Further Experiments on the Feeding of *Calanus finmarchicus*." Biol. Bull., Vol. LXX, No. 2, pp. 308—320, 2 figs. Woods Hole, Mass., 1936.

The nutrition of copepods has been a vexed question ever since Pütter put forward his hypothesis. The food organisms which can be observed and counted in a copepod gut are those with indigestible skeletons (diatoms, peridinians, etc.). The numbers of these which have been counted in any gut are, however, always far below those considered necessary for the nutrition of the copepod as calculated from its oxygen requirements, and the explanation most commonly put forward to account for the difference is that copepods feed largely on organisms which leave no recognizable remains, such as naked flagellates and bacteria. The present paper takes us an important step forward in our knowledge, since it rules out the latter as a main source of food.

The experiments described show that *Calanus* can survive for a time in sterile sea-water but cannot moult in it, nor in sterile sea-water to which large quantities of bacteria have been added, whereas they can live and moult in unfiltered water and, to a less extent, in water passed through filter paper. Calculations of the food value of bacteria and small flagellates and some preliminary measurements of the rate at which *Calanus* can filter water indicate that it cannot feed itself adequately on these organisms. But, as the authors point out, much more needs to be known about the quantity of nannoplankton in the sea, the nutritive values of the different organisms and the effect of environment on the filtering rate of copepods, before any conclusions can be drawn.

The only criticism which might be offered is that the number of *Calanus* used in the experiments is small.

S. M. M.

C. J. Fish. "The Biology of *Calanus finmarchicus* in the Gulf of Maine and Bay of Fundy." Biol. Bull., Vol. LXX, No. 1, pp. 118—141, 11 figs. Woods Hole, Mass., 1936.

"The Biology of *Pseudocalanus minutus* in the Gulf of Maine and Bay of Fundy." Ibid, Vol. LXX, No. 2, pp. 193—216, 9 figs. Woods Hole, Mass., 1936.

"The Biology of *Oithona similis* in the Gulf of Maine and Bay of Fundy." Ibid, Vol. LXXI, No. 1, pp. 168—187, 9 figs. Woods Hole, Mass., 1936.

C. J. Fish and M. W. Johnson. "The Biology of the Zooplankton Population in the Bay of Fundy and Gulf of Maine with special reference to production and distribution." Journ. Biol. Board Canada, Vol. III, No. 3, pp. 189—322, 45 figs. Toronto, 1937.

1) Our knowledge of the life histories and breeding periods of plankton animals is, apart from one or two forms, very scanty, and these papers are welcome as a first contribution to the subject from the North American coast.

The results are based mainly on five series of hauls taken in the Gulf of Maine and Bay of Fundy from April to September, 1932, with additional data from hauls taken in the Bay of Fundy, the outer part of the Gulf and the coast of Nova Scotia.

Calanus finmarchicus is the most abundant zooplankton organism, and its development and dispersal are therefore of special interest. The chief centre of abundance is in the western part of the Gulf of Maine and here

reproduction began in March—April and the resultant nauplii spread rapidly in the surface drift over most of the Gulf and the eastern part of the Bay of Fundy. In the eastern part of the area local reproduction did not begin till about a month later, and this difference persisted during the rest of the year even when the copepods had been dispersed to other parts of the area. The two stocks can therefore be distinguished and their subsequent history followed. The western stock spawned in June—July and possibly a third time in September; the eastern spawned in April—May and July—August. The enormous increase in the volume of the zooplankton in May was caused by copepodites of the western stock. The western part of the Gulf is the centre from which the bulk of the *Calanus* population comes; indeed, the author considers that propagation in the eastern part and the Bay of Fundy is largely, if not entirely, unsuccessful.

The rate of development postulated (2½ months) is slower than that found off the coasts of Great Britain, and approximates to that found off Norway. The winter stock is formed partly from the results of the June spawning and partly from those of later broods. The life of an individual may therefore be as long as 10—11 months, most of which is passed in copepodite stage V.

2) *Pseudocalanus minutus* is second in importance only to *Calanus*, and may outnumber it in inshore areas. There are three stocks present, one originating in the outer and one in the western part of the Gulf, and one in the Bay of Fundy. The first stock begins to reproduce earliest, the second about a month later and the third a month after that; after the first brood the first and third stocks reproduce at about the same time and are not distinguishable.

The most easily traced of the three stocks is that from the western Gulf, and three or possibly four breeding periods were distinguished, March—April, May—June, July—August, and a doubtful one in September. The full cycle from egg to spawning adult takes about two months. The strong counter-clockwise surface drift in the Gulf of Maine disperses the eggs and larvae so thoroughly that, in any series of catches, the nauplii of the dominant stock were found distributed throughout the entire area. The predominance of the late nauplius stages in almost every catch was a most striking feature. The mortality of *Pseudocalanus* at this stage must be enormous and its importance as food for the small predatory forms may be greater even than that of *Calanus*.

As with *Calanus*, breeding in the Bay of Fundy seems to be unsuccessful. The Bay is an area of constant mixing; G r a n and B r a a r u d have shown that phytoplankton production is poor, and there may be too little food for the developing copepods.

3) In the same way a western and an eastern stock of *Oithona similis* can be distinguished and their breeding periods and dispersal are followed. The western stock had four broods, in March, May, July, and September, and the eastern three, in April, June, and August. The life cycle, which takes two months in the early part of the year, is shortened to six weeks in summer. The third brood was numerically the most important and in August the larvae of *Oithona* far outnumbered those of the other copepods. The mortality, however, was enormous, and the adults resulting from this brood were comparatively few. The Bay of Fundy was again found to be unproductive and the copepodites found there were usually immigrants from other areas.

4) The fourth paper is more comprehensive, dealing with all the zooplankton of the same region. A short account of the annual temperature

cycle is followed by an account of numerous drift-bottle experiments. There is a strong counter-clockwise current round the Gulf of Maine, flowing at the rate of 3—6 miles per day, which sends an offshoot into and round the Bay of Fundy. Zooplankton organisms are therefore transported rapidly over the area and may flourish far from the point of origin.

The zooplankton is made up from the following groups: boreal endemic species; northern and southern migrants; neritic plankton species; fish eggs and larvae; larvae of benthonic invertebrates; occasional benthonic invertebrates. Of these the first is by far the most important, forming over 80 % and usually over 90 % by number of the catches. In this group some half-dozen species predominate, the most numerous being *Calanus finmarchicus*. The neritic group consists of copepods, cladocera and medusae and is naturally most abundant in the Bay of Fundy and on the coast of Maine. They are most numerous in summer and although the copepods may have two broods, the other neritic organisms have only one. Fish eggs and larvae occur throughout the year and young *Clupea* are numerous at times. Invertebrate larvae are rather few and, apart from the large numbers of *Balanus* nauplii in spring, are unimportant.

Special attention was given to Passamaquoddy Bay, but the plankton there is poorer than that in the Bay of Fundy, which is itself poorer and less productive than the Gulf of Maine. Endemic boreal species still form the bulk of the catches during most of the year, but neritic species and benthonic larvae are relatively more important in spring and autumn. Hydrographic observations indicate that interchange between the waters of Passamaquoddy Bay and the Bay of Fundy is very slow. There is no support for the idea that the concentration of young herring in the Passamaquoddy region is correlated with a richer or more accessible zooplankton food supply.

It would have added greatly to the value of these interesting papers if the complete data had been published.

S. M. M.

D. S. Raitt. "The Haddock Stocks of the North-East Atlantic, 1916—1935." Fisheries, Scotland, Sci. Invest., 1936, No. I, pp. 32, 7 figs. Edinburgh, 1936.

Innerhalb des Verbreitungsgebietes des Schellfisches gibt es eine Reihe von gesonderten Stämmen, die durch Meeresteile von grösserer Tiefe voneinander getrennt sind. Für jede von ihnen wird auf Grund der vorhandenen Literatur und zum Teil unveröffentlichter Altersbestimmungen die Stärke der einzelnen Jahrgänge, zunächst innerhalb des Zeitabschnitts 1916—1934 zusammengestellt. Die Unterlagen sind sehr ungleichmässig. Während die Stärke der Jahrgänge des Schellfisches der Nordsee zahlenmässig genau festgelegt ist, kann für Island nur eine Einteilung in fünf und für andere Gebiete in drei Stärkegruppen durchgeführt werden, wobei auch noch vielfach Lücken offenbleiben. Es zeigt sich, dass der Ausfall der einzelnen Jahrgänge bei den verschiedenen Stämmen in ungleicher Weise vor sich geht. Bei den benachbarten Gebieten Island und Färöer bestehen zwar nicht gerade Gegensätze, aber auch nicht mehr als zufällige Übereinstimmungen. In der Nordsee verteilen sich gute und schlechte Jahrgänge ganz anders, aber die mit ihr im Zusammenhang stehenden Gewässer, die nördlich von Irland und westlich von Schottland gelegenen, wie Kattegat und Ostsee, zeigen nur unerhebliche Abweichungen, weil ihre Schellfischbestände durch Austausch oder Zuzug in unmittelbarer Verbindung mit denen der Nordsee stehen. Auch unter den Schellfischen der Norwegischen Küste und des Barentsmeeres ist, wie das

noch unzureichende Material erkennen lässt, die Stärke der Jahrgänge anders verteilt. Überall zeigt sich, dass auch innerhalb des Gebietes eines einheitlichen Stammes die Alterszusammensetzung örtlich wechseln kann. Dass in der Regel nicht gleichzeitig überall schlechte Jahrgänge entstehen, ist ein für die Fischerei wichtiges Ergebnis, denn so wird an irgendeiner Stelle immer lohnender Schellfischfang getrieben werden können. Durch entsprechende Beobachtung der Bestände hinsichtlich des vorhandenen Nachwuchses könnten darüber Voraussagen abgegeben werden. *Lb.*

A. Ritchie. "The Food and Feeding Habits of the Haddock (*Gadus aeglefinus*) in Scottish Waters." Fisheries, Scotland, Sci. Invest., 1937, No. II, pp. 1—94, 9 charts. Edinburgh, 1937.

The food and the feeding habits of our principal fishes have formerly been the subject of rather comprehensive studies, for instance, by R. A. Todd (1904—05) for the northern North Sea, and by H. Blegvad (1916) for the inner Danish waters. Whereas in both these papers several species of fish are dealt with, in the paper under review A. Ritchie deals very thoroughly with a single species, the haddock.

The author has investigated the stomach contents of a large number of haddock from the northern and central parts of the North Sea right from the coast of Scotland and southwards to the Dogger Bank and eastwards to the Danish coast and the Norwegian Channel. Also samples of haddock from the coastal waters west and north-west of Scotland have been investigated. The area investigated thus covers the main region in which haddock are fished for. For the investigation the haddocks were sorted in five-centimetre groups (except those up to 20 cm., which were collected as one group). The stomach content of each size-group was examined and recorded separately, the amount of food in the stomachs being obtained by measurement of water displacement, and the percentage frequency of each food species recorded as far as possible.

The stomachs of the pelagic stages of the haddock were not studied. It would, however, be valuable if the author would extend his investigations to include the larval stages also, as it is important to know the food and the feeding habits of the haddock at this early stage of life when the survival of the species is mainly fixed.

The results of the investigations are given in tables showing for each "square" of the area investigated "the relative volume of animal groups (Echinoderms, Crustacea, Annelids, Molluscs and Fish) per 100 fish" of the various size-groups. In addition, tables are given showing for each food species (genus) the percentage frequency in the stomachs. Finally the main results are shown in two charts stating the food animals predominant in the different feeding areas during May—July and August—December.

The principal feeding season is May—December; "it is divisible into two parts — May to July and August to December — the latter of which is characterised by changes in the food over a wide area due chiefly to increased concentration on the consumption of Crustacea and Sandeels." In the different regions various food-animal groups predominate in the stomach contents (Charts IV and V). In the shallower waters various Crustaceans (*Portunus* sp. *Crangon allmanni* and *Calocaris macandrea*) and sandeels predominate, especially during August—December; in deeper areas *Ophiura* and *Echinocyamus* are most common and in still deeper areas Annelids and *Amphiura* (in special cases *Cardium minimum*) constitute the main food. The food of bottom stages of the 0-group (from August) consists of nearly

the same animals as in the older fish. Pelagic feeding (at what season?) of the bottom stages has been observed in a few samples where especially *Limacina retroversa* was found in the stomachs.

Based on the food examinations the author divides the waters investigated in the following feeding areas according to the prevailing food species:

a. *Ophiura affinis—Echinocyamus pusillus* area
b. *Cardium minimum* area
c. Annelid area
d. *Amphiura*—Annelid area
e. *Amphiura* area
f. *Crangon allmanni—Portunus* area
g. *Amphiura—Calocaris macandreae* area.

These areas coincide fairly well with the distribution of the bottom animals as stated by Stephen (1932—33); as the author writes, "there is in fact broad agreement between Stephen's data on the distribution of Echinoderms in the North Sea and the corresponding data from the haddock stomachs."

Finally the author discusses the important question of the relationship between food and growth. He gives evidence of the fact that during the spawning season (January—April) feeding is on a reduced scale, and although the abatement is much greater in the spawning fish than in the young and immature fish, these latter also show a considerable reduction. It is further shown that "the tendency to lower food consumption is apparent in the region of slow growth"; thus the central North Sea, where the growth-rate is slow, is also a poorer feeding area than the eastern and western parts, where the growth-rate is higher.

On the basis of thorough and comprehensive investigations the author has given a clear survey of the food and the feeding habits of the haddock in the North Sea. The paper is of high value for scientists working on fishery problems in the North Sea, but the zoologist working on faunistic and zoogeographical problems will also find important information in the paper. In this connexion it would, however, have been preferable if the author had given for the various samples the dates, or at any rate the month, of collection and, further, for some of the food animals the size of the specimens; this would have made it possible to decide whether some of the seasonal alterations in the food are not caused by a new generation of food animals (e.g., *Portunus,* sandeel) appearing on the sea floor.

Erik M. Poulsen.

P. Jespersen. "The Food of the Herring in the Waters round Bornholm." Medd. Komm. Danmarks Fisk.- og Havunders., Ser. Plankton, Bd. III, No. 2, pp. 40, figs. 15. København, 1936.

Continuing his work on the food of Danish herring, Dr. Jespersen examined the stomach contents of 4,600 herring from the waters round Bornholm, collected during the period July 1932 to December 1935.

He measured the volume of food found in the stomachs, but, except for the larger crustacea and young fish, he did not estimate the number of organisms. Instead he gives figures for "the relative quantity of feeding herring in which the organisms in question were established to constitute part of the stomach contents." He realizes, however, that his method has a very limited value.

His table giving the mean volume of food per herring for each month shows that in 1934 and 1935, which were very good herring years at Bornholm, the quantity of food consumed was more than twice as large as in

1933. The results for the four years were combined and are shown graphically in Fig. 4. This shows that the quantity of food taken rose rapidly after February to a maximum in April; there was then a sharp fall in May, and a more gradual decrease afterwards to a minimum in October, when the herring were spawning; the feeding curve rose again during November and December. The percentage of feeding herring is shown in the same diagram, and the curve agrees very well with that for the volume of food, except that the peak was not so sharp, and extended from March to July.

Compared with North Sea herring, the maximum feeding period was a month earlier, and the quantity of food was smaller. There was also no period when feeding ceased altogether, as is the case with the herring of the southern North Sea in October and November.

Jespersen measured the gonads of the herring from which stomachs were collected, and found that during September and October the largest amount of feeding (40 %—50%) took place amongst those herring which were either "spent" or had undeveloped gonads, while of those with well-developed gonads only 11 % were feeding. He concludes that the spawning herring off Bornholm feed sparsely immediately before and during spawning — a result he had previously noted in herring from the eastern and southern Kattegat and the southern Belt Sea.

His analysis of the stomach contents revealed a definite cycle in the kind of food consumed. In spring, young fish (*Ammodytes*) and small copepods predominated; in summer, copepods and cladocerans were dominant, while after the autumn spawning large crustaceans were the staple winter diet.

The principal copepods in the food were *Pseudocalanus elongatus*, particularly in the early months, *Temora longicornis* throughout the year, and *Eurytemora hirundoides* in summer and autumn. *Mysis mixta* was the most important of the large crustacea, with a considerable maximum in December, while the commonest amphipod was *Gammarus locusta*. The cladocera were almost restricted to the summer months; *Evadne nordmanni* and *Podon* sp. with June maxima, and *Bosmina maritima* with a maximum in September.

In 1931 the herring fishery at Bornholm was exceptionally poor both in quantity and quality, and Jespersen found indications, from a few samples he collected in autumn, that feeding activity was much less than in the four following years. This is an interesting contrast to the English results, which show that 1931 was a rich feeding year for North Sea herring

R. E. S.

J. M. Marchand and W. Taylor. "Savings-Trawl Investigations in South African Waters during 1935." Dep. Comm. and Industr., Fish. and Mar. Biol. Survey Div. Invest. Rep. No. 8, pp. 43, plates 10. Pretoria, 1936.

This paper is a description of the tests of using larger mesh in the cod-end of trawls, that have been carried out in connexion with regulations introduced in the Cape Province.

Fishing for sole (*Austroglossus*) on the grounds of Agulhas Bank was carried out on two ordinary voyages of a commercial trawler, differing from normal commercial practice only in the fact that the upper half of the straight part of the cod-end of the trawl was braided of 3-inch mesh in place of the standard 2½-inch. These voyages were made as a demonstration that voyages with this mesh would pay as well as those with 2½-inch mesh, and that small soles would be released. Comparing the demonstration voyages with ordinary ones, in which the 2½-inch mesh was used, it seems that, if

anything, the 3-inch mesh paid a little better. Regulations to insure the use of the 3-inch mesh were made in September 1935, and, writing four months later, the authors are able to say that the regulations have met with the approval of the fishermen.

Experiments were made, by fishing two vessels against each other, to find what would be the best mesh for improving the exploitation of the stockfish (*Merlucius*). With the ordinary 2½-inch mesh large quantities of unmarketable fish are killed, nearly 50 per cent. of the catch by weight. Very often there are double or triple bags, and a large part of the effort of handling them results in this "dirt", which goes over the side. A mesh of 4 inches reduced this waste to 30 per cent., and, on the average, increased the catch of marketable fish. There were only 16 pairs of comparable hauls, but the same sort of result has now been demonstrated for the fourth time (inshore plaice, haddock, hake, and these stockfish), so there need be no hesitation in accepting it.

The cod-end of 4-inch mesh was, however, obviously weaker than that of 2½-inch mesh, showing more signs of wear and tear, and it seems as if this is the limit to which mesh may be enlarged, if not a little beyond it. The paper finishes with a recommendation in favour of adoption of the 4-inch mesh for the fishery and the use of stronger twine.

There are very good diagrams showing the trawls used, and clear and interesting photographs of cod-ends and catches.

M. G.

A. F. Bruun. "Contributions to the Life Histories of the Deep Sea Eels: *Synaphobranchidae.*" Dana-Rep. No. 9, 31 pp., 1 pl., 17 figs. Copenhagen and London, 1937.

Each Dana-report as it is published bears fresh witness to the foresight and breadth of view of Johannes Schmidt. To Schmidt's own work on the Freshwater Eels is now being added a series of papers on the less familiar members of that specialized order, the Apodes. Dr. Bruun's work, on the Synaphobranchid Eels, is in the true succession from Schmidt's in its exhaustive and logical use of material and data.

The study of the Synaphobranchid larvae received little guidance from what is known of the adults, but its results point the way to an analysis of the adult material in the various museums, which it is hoped may soon be undertaken to make the picture more complete. Bruun concludes that the distribution of the adults is determined by two factors: first, by the position of suitable spawning-areas and the scattering-facilities from them; secondly by upper and lower temperature limits in the depths (usually about 1,000 m.) inhabited by these eels, the lower limit closing to them the Faroe-Shetland Channel, the upper making the Straits of Gibraltar impassable.

The Synaphobranchid Leptocephali are of an easily recognizable type, with "telescopic" eyes. They inhabit deeper layers than normal-eyed larvae, such as those of *Anguilla*, being most frequently taken at depths of 100 to 275 m. below the surface. The Atlantic material was naturally the richest, and in it two species were recognized, and were identified with *S. kaupi* and *S. infernalis*. *S. kaupi* was taken in sufficient numbers to allow the main facts of the life history to be established. In an area extending from north-east of the Antilles and Florida eastwards nearly to the coast of Africa all the larvae taken were less than 80 mm. long, and it is concluded that the spawning area is in this region. A north-eastern area, westwards of the coasts of Portugal and the British Isles, yielded only larvae longer than 80 mm. This indicates a northward and eastward movement during the

larval life, which, it is calculated, lasts from 18 to 22 months. From a scarcer material of *S. infernalis* it is concluded that this spawns near the Antilles, completes its larval life in 8 or 9 months, and does not wander, either as larva or as adult, farther east than about 25° W.

Here follows perhaps the most interesting part of the paper, a comparison between the life histories of the Atlantic species of *Anguilla, Conger,* and *Synaphobranchus.* Each genus has an eastern and a western species, whose spawning areas overlap, determined by conditions of temperature and salinity that are similar, though not identical in range, for all three genera. In adult life the habitats are as diverse as possible, for *Anguilla* fresh water, for *Conger* coastal waters, for *Synaphobranchus* the deep sea. And it is here noted that it is the older larvae of *S. kaupi,* not the adults, that are restricted to the eastern Atlantic, and allow it to be considered an eastern Atlantic species. Whether the adults wander westwards without the urge of the spawning habits is not known, nor whether they survive spawning, but a number have been captured on the American side.

The Indo-Pacific material is much smaller, but some interesting facts emerge, not the least of which is the presence in the Sulu and Mindanao Seas of Leptocephali well enough defined to be regarded as a systematic unit. Bruun compares this deep basin with its shallow thresholds to the Mediterranean, from which *Synaphobranchus* is absent, and concludes that the Sulu Sea form is living very close to the upper temperature-limit for the genus. Incidentally it is pointed out that this form provides yet another instance of the correlation between low numbers of myotomes and higher temperatures.

This is a paper that repays careful study both for the generous quantity of facts and suggestions presented and for the fascinating methods of analysis and synthesis employed.

E. Trewavas.

L. Bertin. "Les Poissons Abyssaux du Genre *Cyema* Günther (anatomie, embryologie, bionomie)." Dana-Rep. No. 10, 30 pp., 24 figs. Copenhagen and London, 1937.

Cyema is a small, black, compressed, deep-sea eel, with slender, avocet-like jaws, and with a short, abruptly ending tail. Within the last few years its larva has been identified and its anatomy described, and now with the publication of Dr. Bertin's memoir, from being one of the most obscure deep-sea fishes it has become one of the best known. Nevertheless the problem of its nearest relationships remains unsolved. Up to the present it has been placed within the Order Apodes, but Dr. Bertin makes the suggestion that it may have more affinity with *Saccopharynx* and *Eurypharynx.* In the opinion of the reviewer this suggestion is not well supported. One may follow the author in abandoning the idea of very close relationship with *Nemichthys* (the Snipe-eel) but there still remains the fact that the ethmoid region and upper jaw are of a specialized Apodal type, and are quite unlike the problematical structures found in the Lyomeri. The size and position of the branchial apparatus are also as in Apodes.

It was already known that the theory that the short body of *Cyema* is secondarily reduced from an elongate type received no support from the development. The larva is leaf-shaped and from the beginning has only the adult number of myotomes (about 76). Dr. Bertin has sought enlightenment on the meaning of the abrupt end of the body in the structure of the caudal fin, and has been answered by another question. The caudal extremity is almost perfectly symmetrical, within and without. The tail-fin consists

mainly of dorsal and anal rays, the supports of which are, even after metamorphosis, separated out of an originally continuous skeletal plate. The posterior parts of this plate remain as expanded epural and hypural, bearing respectively two and three true caudal rays. Dr. Bertin interprets this as an atavistic return to true diphycercy, caused by arrested development. True diphycercy is extremely rare, and as far as the reviewer is aware, occurs only in tapering extremities, not involving expanded supports. An alternative interpretation suggests itself, namely, that the ancestor of *Cyema* may have had a long tapering tail, in which, as in some Nemichthyidae, the true caudal had vanished; that during its evolution the terminal part tapered away altogether; and that in the truncated stump *Cyema* has rediscovered a caudal fin, a new expanded caudal that has never had anything to do with heterocercy. The difference between this interpretation and Bertin's may appear merely academic, but in fact it is the only interpretation of the ontogeny that is in line with the plausible theory that *Cyema* is secondarily short. It is supported by the fact, pointed out by the author, that whereas in ordinary Teleost (and Apodal) development the hypurals develop before the dorsal and anal fin-supports, in *Cyema* the reverse is true.

The author touches on a field of enquiry that deserves the attention of physiologists when he describes the weakly and imperfectly ossified condition of adult *Cyema* as "rachitic". A comparative chemical and histological study of the bones of deep-sea fishes would probably yield interesting results.

Dr. Bertin has seen nearly all the larval and adult *Cyema* in European collections, and he concludes that they represent a single species, with a world-wide distribution. There is no evidence of restricted spawning areas, except that larvae were all taken in warm latitudes, the great majority between 100 and 300 m. below the surface.

The paper is illustrated by a number of clear figures.

E. Trewavas.

V. D. van Someren. "A Preliminary Investigation into the Causes of Scale Absorption in Salmon (*Salmo salar*, Linné)." Fisheries, Scotland, Salmon Fish., 1937 No. II, pp. 12, 1 fig. Edinburgh, 1937.

That the scales of migratory Salmonidae undergo absorption whilst the fish are in fresh waters on their spawning migration is a well-known fact of great importance, for it is the scar produced when the scale is repaired that forms the "spawning mark" and enables the life history of the fish to be deduced from a study of the scales.

In a former paper of this series (Fisheries, Scotland, Salmon Fish., 1935 No. IV) Crichton suggested several explanations of this absorption, among them that it was due to the necessity of making good some substance, perhaps calcium, necessary for the ripening of the gonads. Van Someren has followed up this suggestion by attempting to correlate the calcium content of the blood serum with the degree of scale absorption. In this he was unsuccessful although he found a very interesting variation in the amount of calcium. In females the value rises slowly from the time the fish enters fresh water until they are ripe, when it shows a sudden drop, but in males (which show far more extensive scale absorption) the amount of calcium remains steady until after spawning time, when it drops to the same low level as in the female. The mechanism of calcium control is discussed and it is suggested that it is a function, direct or indirect, of the gonads.

The author then examines other theories and concludes that the scales are probably absorbed to supply minerals necessary for the general metabolism

of the body while the fish are in fresh water when they are taking little or no food. The increased absorption in male salmon is correlated with the development of secondary sexual characters, the large teeth and the gib. Although he produces no experimental evidence for this view, his reasoning is sound and convincing.

F. T. K. Pentelow.

C. McC. Mottley. "The Number of Vertebrae in Trout (*Salmo*)." Journ. Biol. Board Canada, Vol. III, No. 2, pp. 169—176. Toronto, 1937.

The importance of vertebral counts in fishery research is well known to all biologists and this paper should be of wide interest. Mottley has investigated the variation in the number of vertebrae in four species of the genus *Salmo* and in some populations of *S. gairdneri* in which the ancestry and conditions of development were known.

He found that the average number in the European species *salar* (59) and *trutta* (58·3) was lower than in the American *gairdneri* (63·5) and *clarkii* (62·5) although they were reared in the same hatchery under similar conditions. Within the species *gairdneri*, however, he found considerable and significant differences between various populations. Hatchery reared fish usually differed from those taken from the natural environment and even from their own parents, as well as varying with different experimental conditions. He found, for example, that six broods of fingerlings reared separately in the same hatchery, and all the progeny of fish having 64 vertebrae, gave vertebral counts ranging from 63 to 67, and each brood had a mean differing from the others and from the mean of the total. It was found that these differences were, with one exception, statistically significant. These broods did not all hatch at the same time and the author suggests that this was the cause of the variation. In subsequent experiments he showed that the number of vertebrae in trout could be modified by environmental conditions, the most important factor being, apparently, temperature, as has been postulated on other grounds by Jordan and Schmidt.

So far as this species is concerned the question whether the number of vertebrae is determined by heredity alone or whether environmental conditions can modify, within limits, the number finally laid down, has been definitely answered.

Mottley concludes, "The fact that the number of vertebrae in trout is capable of modification by changing the environmental conditions during development suggests caution in the use of it as a character for identifying populations of trout." May I suggest that this sentence is much more easily understood if the word "races" with its genetic associations, be substituted for "populations"?

F. T. K. P.

A. E. Hopkins. "Adaptation of the Feeding Mechanism of the Oyster (*Ostrea gigas*) to Changes in Salinity." Bull. Bureau of Fish., Vol. XLVIII, No. 21, pp. 345—364, 11 figs. Washington, D. C., 1936.

This paper continues the work of the author on the adaptation of the Japanese oyster to variations in the environment. On account of the variability between individuals under similar conditions, it was found necessary to record the behaviour of selected specimens over long periods of time, during which several changes in the salinity of the medium were made. Continuous kymograph records were made in each case of the degree of openness of the shell and the relative amount of water pumped.

In this paper the behaviour of seven oysters is recorded, in each instance over a period of several days during which the salinity of the medium was varied at intervals. The experiments form a logical series in that the later ones follow up and elucidate the results obtained in the earlier experiments.

Any significant change in the salinity causes an immediate slowing or cessation of pumping. Recovery depends upon the amplitude and direction of the change. While only a few hours may be required for adaptation to a higher salinity, several days may be necessary for recovery following a similar change in the opposite direction. Adaptation to a marked lowering of salinity, e.g., from 28 to 20 parts per mille, occupies several days, and it seems probable that the rate of pumping water never reaches the values observed at the higher salinity. If the salinity is reduced below 20 parts per mille the oyster becomes increasingly sensitive, and the time needed for recovery is increased. At salinities of about 15 per mille adaptation to a lower level of pumping occurs, but occupies several days, while if the salinity is reduced still further the quantity of water pumped is markedly reduced and the behaviour of the adductor muscle is irregular and abnormal. At a salinity of 13 parts per mille a little water is pumped, and recovery is achieved on restoration of normal conditions, but at salinities of about 10 per mille no such recovery was apparent even after 20 days. In this instance the shells were open to an abnormal degree and apparently the pumping mechanism of the gills was considerably damaged; recovery, however, occurred in a few weeks in running aquarium water. Adaptation to an increase in salinity was always comparatively rapid, the gills becoming adjusted very quickly, while the adductor muscle became adjusted more slowly, the shells remaining close together for several hours and obstructing the flow of water. Adjustment to salinities considerably above those of ocean water was found to be very rapid.

The only criticism which could be made of the set-up of the experiment concerns the sudden changes of salinity. Under natural conditions all salinity changes are gradual, and the experimental difficulties in the way of effecting such gradual changes in the laboratory are few.

Comparing the results of this study with those obtained with *Mytilus* in Britain, it appears probable that adaptation follows the same general principles. Mussels, even more than oysters, are subjected to rapid changes in the salinity of the environment. It has been shown that mussels will pump water, although at rates below the normal, at a salinity of approximately 15 per mille, but that below 15 per mille normal pumping does not occur. Adaptation to very low salinities may, however, be brought about over a long period. It is hoped that with the evolution of good experimental equipment by H o p k i n s further work on other lamellibranchs of economic importance will follow.

H. A. C.

J. H. Orton. "Observations and Experiments on Sex-Change in the European Oyster, *Ostrea edulis* L. Part V. A simultaneous study of spawning in 1927 in two distinct geographical localities." Mém. Musée Roy. d'Hist. Nat. Belgique, 2. Sér., Fasc. 3, pp. 997—1056, 4 figs. Bruxelles, 1936.

In this paper a detailed comparison is made between the spawning phenomena exhibited by the populations of oysters (*Ostrea edulis*) in two widely separated localities on the English coast, viz. in the estuaries of the Blackwater and the Fal. The method employed was the examination and

determination of the sex-physiological condition of large weekly samples of oysters from the two localities. At the same time records of sea temperature in the two localities were obtained.

Spawning began in each locality when the sea temperature in its gradual seasonal rise reached, and was maintained at, 15°C. On the Blackwater spawning began on May 31st coincidently with the attainment of the above temperature, and continued until the middle of August, being heaviest at mid-June. On the Fal spawning did not begin until June 11th or 12th, and was arrested at the end of June by a fall of sea temperature below 15°C. Spawning, however, became general during the second week in July and continued until mid-August. 20 % of the population of oysters on the Fal matured as females during August but were unable to spawn, despite the prevalence of sea temperatures above the spawning limit. This phenomenon is tentatively correlated with high and fluctuating salinities, but requires further study. On the Blackwater the percentage of mature females which failed to spawn was very small.

Data are given which indicate that eggs develop to the coloured veliger stage in the oyster in one week, and that at temperatures of 15°—16°C. the total period of incubation is 7—10 days. It is probable, however, from the earlier work by the author and from the experience of those who have worked with oysters in enclosed basins, that the liberation of the larvae from the mantle cavity may be delayed if unfavourable circumstances supervene, and hence the total period of incubation may be prolonged. It is known, for example, that the larvae at liberation may vary in size from 0·16—0·21 mm., indicating a difference in age of not less than 3 or 4 days. The question of the factors affecting the liberation of larvae from the mantle cavity has not yet been examined.

The author discusses the spawning stimulus and the suggestion is advanced that it may be bound up with the changes in oxygen consumption of the parent oysters as the eggs ripen, and the variation in the oxygen supply of the habitat.

No lunar periodicity occurred during 1927 in the spawning of oysters from either the Blackwater or the Fal, and it is doubtful whether such lunar periodicity is a regular feature in the spawning of populations of *Ostrea edulis*, although further data are desirable from the French and Italian beds, where the sea temperatures are maintained above the spawning limit throughout the summer.

From the data given it is clear that 50 % or more of the adult oysters, on both the Blackwater and Fal grounds, mature as females in successive years. Hence, since maleness is rapidly assumed after spawning, it is clear that reversion to the female condition must occur on the average every second summer, while a certain percentage of the population must revert to the female condition in less than 2 years. Comparable percentages of females are shown to have occurred on Danish, German, Dutch, and probably French grounds. More information is needed from the French and Italian beds and from the warmer Norwegian oyster-polls. In populations of oysters under enclosed conditions it is probable that the percentage maturing as females in each year is considerably smaller, and this confirms the author's view that abundant food supply is the most potent factor in bringing about rapid reversion to the female stage.

This paper is the fifth part of a comprehensive study of spawning and sex-change in *Ostrea edulis*, which the author began in 1920. The results obtained so far have been extraordinarily valuable and have thrown a flood of light upon a subject of which we were almost completely ignorant. When

it is remembered that the state of the British native oyster industry can only be described as critical, the value becomes obvious of any studies which help us to a fuller understanding of the biology of the oyster.

H. A. C.

P. S. Galtsoff, H. F. Prytherch and J. B. Eagle. "Natural History and Methods of Controlling the Common Oyster Drills (*Urosalpinx cinerea* Say and *Eupleura caudata* Say). U.S. Dep. Comm., Bureau of Fish., Fish. Circ. No. 25, 24 pp., 13 figs. Washington, D. C., 1937.

This paper is a preliminary account of investigations undertaken by the United States Bureau of Fisheries into the life history of the common oyster drills of the Atlantic and Gulf States, with the object of discovering effective methods for their control. The species dealt with, *Urosalpinx cinerea* Say and *Eupleura caudata* Say, are small, somewhat whelk-like sea snails, which are commonly found on the oyster bottoms in certain parts of the U. S. A.; but while they appear to be equally destructive to the oysters, *Urosalpinx*, owing to its greater abundance, is to be considered the greater pest. Both species destroy oysters by boring through the shell by means of their radula, and then devouring the flesh at leisure. In certain localities of Long Island and Chesapeake Bay, sixty to seventy per cent. of the seed oysters are stated commonly to be destroyed by these pests, while not infrequently the entire crop may be lost as a result of their activities. These two forms have been recorded from English waters, having been introduced with consignments of imported American oysters.

In a useful account of the life history, the authors state that these two species are not tolerant of water of low salinity, and that they hibernate in the mud during cold weather, while their powers of multiplication depend somewhat on the kind of food they consume. They show a decided preference for mussels over oysters, and they also eat slipper — shells, clams, and barnacles. They exhibit a marked partiality for young oysters.

The various methods of mechanical and biological control are described very fully. These comprise the prevention of the spread of the pests into new areas and the removal of the drills from infested areas and their destruction. A considerable degree of success in reducing the number of borers on infested beds attended the use of baited wire traps set out in various ways, and the destruction of the spawn taken up on various forms of collectors. The authors are of the opinion that drill control is of definite economic value. This interesting and useful paper contains a number of figures and diagrams illustrative of the text.

F. S. W.

C. L. Newcombe. "Growth of *Mya arenaria* L. in the Bay of Fundy Region." Canadian Journ. Res., Vol. 13, Sec. D, pp. 97—137, 8 figs. Ottawa, 1935.

This paper deals with the growth of *Mya arenaria* L. in the Bay of Fundy, especial attention being devoted to the validity of the growth-rings on the shell for age determination, to ascertaining rate of growth for the district, and the effect of certain environmental factors on distribution, growth-rate, and survival. The material was taken from several different localities and levels, and the animals used to determine increments of growth in nature under different experimental conditions were enclosed in wire boxes, which were placed in the desired natural habitat. Growth was found

to be relatively rapid during the first four years, after which it decreased in a pronounced manner. In 1931, the growth period was from May to August inclusive; in 1930, it continued until December 1st, but this is believed to be unusually late for this area. The investigation showed that variations in seasonal growth-rates during the same and different years corresponded with fluctuations in the abundance of diatoms, and not with temperature, and that the rate of growth varied with the time of submergence. The rate of growth at different levels and seasons is very fully treated. The author shows that the annual growth-rings serve as a criterion for the determination of age and the rate of growth, although it is necessary to use care in distinguishing them from other rings which may be formed as the result of various causes. Various other aspects of the biology of *Mya arenaria* are treated in this valuable paper, which contains a number of graphs and figures.

F. S. Wright.

Current Bibliography.

Prepared by the Editor with the assistance of Miss Thursby-Pelham.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

1) General Oceanography.

1) a Expeditions.

Beaugé, L. Recherches Françaises faites dans le Secteur Nord-Ouest et particulièrement à Terre-Neuve depuis l'Année 1934. Cons. Perm. Internat. p. l'Explor de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 3—4, Copenhague, 1937.

Breitfuss, L. Die driftende Nordpolstation der U.S.R.R. und ihre Ergebnisse. Petermanns Mitt., LXXXIII. 284—86, Gotha, 1937.

Defant, A. Die erste Teilfahrt der neuen Deutschen Nordatlantischen Expedition des "Meteor", Februar bis Mai 1937. Forsch. und Fortschr., XIII, 299—300, Berlin, 1937.

R. N. R. B. The Soviet North Polar Station. Nature, CXL, 1040—041, London, 1937.

1) b Institutes.

Anon. Liverpool Observatory and Tidal Institute. Annual Report 1936. Liverpool, 1937.

Anon. Scottish Marine Biological Association. Annual Report 1936—37. Glasgow, 1937.

Heinrici, C. Die Arbeiten der Deutschen Wissenschaftlichen Kommission für Meeresforschung. Jahresber. Deutsch. Fisch. 1936, 252—72, Berlin, 1937.

Higgins, E. Progress in Biological Inquiries 1935. U.S. Bureau Fish., Admin. Rep. No. 26, Washington, 1937.

International Council. Procès-Verbaux (Juillet — 1937). Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 1ère Part., Copenhague, 1937.

International Council. Rapport Administratif (1936—1937). Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 2ème Part., Copenhague, 1937.

Newfoundland. Report of the Fisheries Research Committee 1937. Dept. of Nat. Resources, St. John's, 1937.

Newfoundland. Report of the Provincial Fisheries Department for 1936. Prov. Brit. Columbia, Rep. Prov. Fish. Dept. for the Year ended December 31st, 1936, 7—25, Victoria, B. C., 1937.

Spiess, H. C. Sechzig Jahre "Aus dem Archiv der Deutschen Seewarte". Ann. der Hydrogr. usw., LXV, 467—78, Berlin, 1937.

2) Hydrography.

2) a Apparatus and Methods.

Gripenberg, S. A Simplified Method for the Determination of Calcium in Sea Water. Journ. du Conseil, XII, 284—92, Copenhague, 1937.

Stoll, K. Analysis of Nitrogen Compounds in Sea Water. Zeitschr. Anal. Chem., CIX, 5—15, Wiesbaden, 1937.

Tibby, R. B. Drift Bottles released off Coast of Southern California. Science, N.S., LXXXVI, 328—29, U.S.A., 1937.

2) b Surveys.

Beaugé, L. Relevés hydrographiques exécutés au cours de la 1ère croisière (21 novembre 1933 — 4 janvier 1934), de la 2ème croisière (10 mai — 3 juillet 1934), de la 3ème croisière (1er septembre — 8 novembre 1934) et de la 4ème croisière (8 mai — 12 juillet 1935). Rev. Trav. Office des Pêches Marit., X, 117—231, Paris, 1937.

2) c Chemistry of Sea Water.

Atkins, W. R. G. British Fisheries, Phosphate and the Solar Radiation Constant. Nature, CXLI, 77—78, London, 1938.

Cooper, L. H. N. Oxidation-Reduction Potential in Sea Water. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 167—76, Cambridge, 1937.

Cooper, L. H. N. On the Ratio of Nitrogen to Phosphorus in the Sea. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 177—82, Cambridge, 1937.

Cooper, L. H. N. The Nitrogen Cycle in the Sea. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 183—204, Cambridge, 1937.

Gripenberg, S. The Calcium Content of Baltic Water. Journ. du Conseil, XII, 293—304, Copenhague, 1937.

Harvey, H. W. The Supply of Iron to Diatoms. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 205—20, Cambridge, 1937.

Harvey, H. W. Note on Colloidal Ferric Hydroxide in Sea Water. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 221—26, Cambridge, 1937.

Legendre, R. Bibliographie complémentaire sur la concentration en ions hydrogène de l'eau de mer (1925—1935). Bull. Inst. Océanogr., No. 724, Monaco, 1937.

Netchaeff, A. et Tcherneff, S. Quelques Notes sur la Hydrologie du Lac de Varna. Trav. Stat. Ichtyol. Sozopol — Bulgarie, T. V, 20—34, 1937. (In Bulgarian, French Résumé).

Seiwell, H. R. The Oxygen-Poor Layer in the Western North Atlantic. Journ. du Conseil, XII, 277—83, Copenhague, 1937.

2) d Physical Properties: General.

Brooks, C. E. P. The unequal Heating of Land and Water. Meteor. Mag., LXXII, 153—56, London, 1937.

Eggvin, J. New Oceanographic Investigations in the Northern North Sea. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 56—62, Copenhague, 1937.

Tcherneff, S. Observations Hydrologiques dans la Zone côtière bulgare. Trav. Stat. Ichtyol. Sozopol — Bulgarie, T. V, 35—44, 1937. (In Bulgarian, French Résumé).

2) e Temperature.

Demel, K. Température des Eaux Côtières Polonaises de la Baltique en 1934—1935. Archiv. d'Hydrobiol. et d'Ichtyol., XI, 24—46, Suwalki, 1938. (In Polish, French Résumé).

Demel, K. La Durée de l'Insolation et la Température des Eaux Côtières à Hel en 1932—1936. Archiv. d' Hydrobiol. et d'Ichtyol., XI, 83—95, Suwalki, 1938. (In Polish, French Résumé).

Gassiot, J. La Température de l'Aigua de Mar a la Platja de Barcelona i la seva Variacio Annual. Servei Met. de Catulunya, Notes d'Estudi, No. 61, 1936.

Thomsen, H. Variations of the Surface Temperature at Selvogsbanki, Iceland, during the Years 1895—1936. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 51—55, Copenhague, 1937.

Tully, J. P. Why is the Water along the West Coast of Vancouver Island so cold? Progress Rep. Pacific Biol. Stat., Nanaimo, B.C., and Pacific Fish. Exper. Stat., Prince Rupert, B.C., No. 34, 13—15, Canada, 1937.

Volz, P. Der jährliche Temperaturgang im Meere und sein Einfluss auf die geographische Verbreitung und die Tiefenverbreitung mariner Bodentiere. Forsch. und Fortschr., XIII, 300—01, Berlin, 1937.

2) f Submarine Illumination.

Ålvik, G. Über Lichtabsorption von Wasser und Algen in natürlichen Gewässern. Bergens Mus. Årbok 1937, Nr. 2, (Naturvid. rekke), 1—63, Bergen, 1937.

Atkins, W. R. G. British Fisheries, Phosphate and the Solar Radiation Constant. Nature, CXLI, 77—78, London, 1938.

Jenkin, P. M. Oxygen Production by the Diatom *Coscinodiscus excentricus* Ehr. in Relation to Submarine Illumination in the English Channel. Journ, Mar. Biol. Assoc. U.K., N.S., XXII, 301—44, Cambridge, 1937.

Utterback, C. L. and Miller, E. K. Variations in Components of Submarine Daylight for 1935 and 1936. Journ. du Conseil, XII, 305—10, Copenhague, 1937.

2) h Currents and Oceanic Circulation.

Carruthers, J. N. Continuous Current Observations for Fishery Application. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 16—27, Copenhague, 1937.

Hachey, H. B. Is the Gulf Stream coming closer? Progress Rep. Atlant. Biol. Stat., St. Andrews, N.B., and Atlant. Fish. Exper. Stat., Halifax, N.S., No. 20, 11—14, Canada, 1937.

Scherhag, R. Die Erwärmung der Arktis. Journ. du Conseil, XII, 263—76, Copenhague, 1937.

Vallaux, C. Le Gulf Stream. Rev. Gen. des Sci., Paris, 31—IX—37.

van Veen, J. Current Measurements from Dutch Lightships. Journ. du Conseil, XII, 335—36, Copenhague, 1937.

Wüst, G. Neuere Auffassungen über das Wesen des Golfstromsystems und die Benennung seiner Glieder. Seewart, VI, 359—67, Hamburg, 1937.

2) i Tides and Sea Level.

Hesse, I. Über die Ermittlung der Brueckner schen Klimaperiode aus Seespiegelschwankungen nach der Fuhrichschen Methode. Gerlands Beitr. z. Geophys., LI, 29—34, Leipzig, 1937.

Stenij, S. E. Über das Hochwasser im Finnischen Meerbusen am 23. September 1924. Konferenz Baltisch. Staat. Finnland, Juni 1936, Ber. 15D, Helsingfors, 1936.

Stenij, S. E. Tide Tables. Liinahamari 1938 (Lat. 69°38·5'N. Long. 31°22'E.). Merentutkimuslaitos, Helsinki, 1938.

2) j Geography, Geology and Bottom Deposits.

Furnestin, J. Compte-rendu de Dragages Géologiques de la 4ème Croisière (8 mai —11 juillet 1935). Rev. Trav. Office des Pêches Marit., X, 233—58, Paris, 1937.

Monaco. General Bathymetric Chart of the Oceans. Information concerning the preparation of the Third Edition of Sheet B1 North Atlantic Ocean. Internat. Hydrogr. Bur., Spec. Publ. No. 30 — Pt. B, Monaco, 1937.

Piggot, C. S. Core Samples of the Ocean Bottom. Ann. Rep. Smithsonian Inst. 1936, 207—16, Washington, D.C., 1937.

Rivière, A. Contribution à l'Étude Géologique des Sédiments Sableux. Ann. de l'Inst. Océanogr. de Monaco, N.S., XVII, 213—40, Paris, 1937.

Schott, G. Flächeninhalt der natürlichen Regionen der Ozeane. Petermanns Mitt., LXXXIII, 252, Gotha, 1937.

Shepard, F. P. Shifting Bottom in Submarine Canyon Heads. Science, LXXXVI, 522—23, U.S.A., 1937.

Wiseman, J. D. H. Geological and Mineralogical Investigations. I. Basalts from the Carlsberg Ridge, Indian Ocean. John Murray Exped. 1933—34, Brit. Mus. (Nat. Hist.), Sci. Rep., III, 1—30, London, 1937.

2) k Ice.

Anon. Sea-Ice Conditions at the Coast of Latvia during the Winter 1936/37. Hydrogr. Sect. Latvian Mar. Depart., Riga.

Anon. Is- og Besejlingsforholdene i de danske Farvande i Vinteren 1936/37. Stat. Isbrydnings- og Ismeldingstjeneste, Copenhagen, 1937.

Jurva, R. Über die Eisverhältnisse des Baltischen Meeres an den Küsten Finnlands. Merentut. Julk., No. 114, Helsinki, 1937.

2) l Meteorology.

Anon. Bibliography of Meteorological Literature. Royal Meteor. Soc., IV, No. 3, (Jan. to June 1937), London, 1937.

3) Plankton.

3) a Apparatus and Methods.

Braarud, T. A Quantitative Method for the Experimental Study of Plankton Diatoms. Journ. du Conseil, XII, 321—32, Copenhague, 1937.

Buchanan-Wollaston, H. J. Two Technical Notes. Journ. du Conseil, XII, 333—34, Copenhague, 1937.

Gohar, H. A. F. The Preservation of Contractile Marine Animals in an expanded Condition. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 295—300, Cambridge, 1937.

Pierce, E. L. A Plankton Collector for Fast Towing. Nature, CXL, 1014, London, 1937.

3) c Phytoplankton.

Ålvik, G. Über Lichtabsorption von Wasser und Algen in natürlichen Gewässern. Bergens Mus. Årbok (Naturvid. rekke), 1937, Nr. 2, 1—63, Bergen, 1937.

Bernard, F. Résultats d'une année de recherches quantitatives sur le Phytoplancton de Monaco. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 28—39, Copenhague, 1937.

Clarke, G. L. On Securing Large Quantities of Diatoms from the Sea for Chemical Analysis. Science, N.S., LXXXVI, 593—94, U.S.A., 1937.

Garstang, W. On the Size-Changes of Diatoms and their Oceanographic Significance. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 83—96, Cambridge, 1937.

Gross, F. The Life History of Some Marine Plankton Diatoms. Phil. Trans. Roy. Soc. London, Ser. B, CCXXVIII, 1—47, London, 1937.

Harvey, H. W. The Supply of Iron to Diatoms. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 205—20, Cambridge, 1937.

Jenkin, P. M. Oxygen Production by the Diatom *Coscinodiscus excentricus* Ehr. in Relation to Submarine Illumination in the English Channel. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 301—44, Cambridge, 1937.

Pavillard, J. Les Péridiniens et Diatomées pélagiques de la Mer de Monaco pendant les Années 1912, 1913 et 1914. Bull. Inst. Océanogr., No. 727, Monaco, 1937.

Pavillard, J. Les Péridiniens et Diatomées pélagiques de la Mer de Monaco de 1907 à 1914. Observations générales et conclusions. Bull. Inst. Océanogr., No. 738, Monaco, 1937.

3) d Zooplankton.

Ellis, J. M. The Morphology, Division, and Conjugation of the Salt-Marsh Ciliate *Fabrea salina* Henneguy. Univ. of Calif., Publ., in Zool., XLI, 343—88, Berkeley, 1937.

Garstang, W. On the Anatomy and Relations of the Appendicularian Bathochordaeus, based on a New Species from Bermuda (*B. stygius*, Sp. N.). Linn. Soc. Journ., Zool., XL, 1937.

Gibbons, S. G. Variations in Copepod Development. Nature, CXL, 1064—65, London, 1937.

Harvey, H. W. Note on Selective Feeding by *Calanus*. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 97—100, Cambridge, 1937.

Jepps, M. W. Note on Apstein's Parasites and some very early Larval Platyhelminthes. Parasitol., XXIX, 554—58, Cambridge, 1937.

Joubin, L. Cours d'Océanographie biologique. Bull. Soc. d'Océanogr. de France, XVII, 1670—79, Paris, 1937.

Lambert, F. J. Jellyfish. The Difficulties of the Study of their Life History and other Problems. Essex Naturalist, XXV, 70—86, Buckhurst Hill, 1936.

Lebour, M. V. The Newly Hatched Larva of *Spirontocaris spinus* (Sowerby) var. *lilljeborgi* Danielssen. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 101—05, Cambridge, 1937.

Lebour, M. V. The Eggs and Larvae of the British Prosobranchs with Special Reference to those living in the Plankton. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 105—66, Cambridge, 1937.

Moore, H. B. Marine Fauna of the Isle of Man. Proc. and Trans. Liverpool Biol. Soc., L, Liverpool, 1937.

Prenant, M. Leçons de Zoologie. Prochordés — Tuniciers. Actual. Sci. et Indust., No. 380, Paris, 1936.

Rose, M. Copépodes Bathypélagiques de la Baie d'Alger. Ann. Inst. Océanogr. Monaco, XVII, 151—74, Paris, 1937.

Toschi, A. Ricerche sul plancton delle valli della Mesola. Boll. Pesca, Piscicolt. e Idrobiol., XIII, 241—61, Roma, 1937.

Wailes, G. H. Plankton of the Bermuda Oceanographic Exhibition. I, II, Protozoa. Zoologica, XXI, 75—84, New York, 1936.

3) e Physiology and Behaviour.

Hyman, L. H. The Water Content of Medusae (*Aurelia*). Bull. Mt. Desert Is. Biol. Lab. 1938, 23, Salsbury Cove, Me., 1938.

4) Organic Production.

4) b Bacteria.

Trawinski, A. Études sur les Microbes et la putréfaction de la chair de quelques genres de poissons comestibles. Bull. Inst. Océanogr., No. 735, Monaco, 1937.

Waksman, S. A., Stokes, J. L. and Butler, M. R. Relation of Bacteria to Diatoms in Sea Water. Journ. Mar. Biol. Assoc. U.K., N.S., XXII. 359—74, Cambridge, 1937.

5) Bottom Fauna and Flora.

5) a Apparatus and Methods.

Gohar, H. A. F. The Preservation of Contractile Marine Animals in an Expanded Condition. Journ. Mar. Biol. Assoc. U.K., N.S. XXII, 295—300, Cambridge, 1937.

Rees, W. J. and Russell, F. S. On Rearing the Hydroids of Certain Medusae, with an Account of the Methods Used. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 61—82, Cambridge, 1937.

5) b Systematics and Development.

Adam, W. Note sur les Céphalopodes. VI. Une nouvelle espèce d'Octopus (*Octopus hummelincki* sp. nov.) des Indes Occidentales Néerlandaises. Bull. Mus. Roy. d'Hist. Nat. de Belgique, XII, No. 40, Bruxelles, 1936.

Ankel, W. E. *Prosobranchia.* Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), XXIX, Teil IX.b1, 1—240, Leipzig, 1936.

Arndt, W. *Porifera.* Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), XXVII, Teil III.a1, 1—140, Leipzig, 1935.

Beier, M. Some Remarks of *Ellingsenius indicus* Chamberlin (Pseudoscorpionidea). Ann. and Mag. Nat. Hist., 10th Ser., XX, 633—34, London, 1937.

Berkeley, E. and C. Notes on Polychaeta from the Coast of Western Canada. II. Syllidae. Ann. and Mag. Nat. Hist., 11th Ser., I, 33—49, London, 1938.

Calman, W. T. The Type-Specimens of *Pallene australiensis* Hoek (Pycnogonida). Ann. and Mag. Nat. Hist., 10th Ser., XX, 530—34, London, 1937.

Cattley, J. G. The Occurrence of *Athelges paguri* (Rathke) in the Branchial Chamber of *Eupagurus bernhardus.* Ann. and Mag. Nat. Hist., 11th Ser., I, 239—40, London, 1938.

Coen, G. Nuovo saggio di una Sylloge Molluscorum Adriaticorum.. R. Com. Talassogr. Ital., Mem. CCXL, Venezia, 1937.

Costello, H. M. and Costello, D. P. A New Species of *Polychoerus* from the Pacific Coast. Ann. and Mag. Nat. Hist., 11th Ser., I, 148—55, London, 1938.

Fergusen, F. The Morphology and Taxonomy of *Macrostomum beaufortensis* n. sp. Zool. Anz., CXX, 230—35, Leipzig, 1937.

Friedrich, H. *Nemertini.* Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), XXX, Teil IV.d, 1—60, Leipzig, 1936.

Frizzell, D. L. Preliminary Reclassification of Veneracean Pelecypods. Bull. Mus. Roy. d'Hist. Nat. de Belgique, XII, No. 34, Bruxelles, 1936.

Heath, H. The Anatomy of some Protobranch Mollusks. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2ème Ser., Fasc. X, Bruxelles, 1937.

Herter, K. *Herudinea.* Tierwelt d. Nord- u. Ostsee. (Grimpe u. Wagler), XXIX, Teil VI.c2, 45—106, Leipzig, 1936.

Keen, A. M. Nomenclatural Units of the Pelecypod Family Cardiidae. Bull. Mus. Roy. d'Hist. Nat. de Belgique, XIII, No. 7, Bruxelles, 1937.

Leloup, E. Trois Anomalies chez des Amphineures. Bull. Mus. Roy. d'Hist. Nat. de Belgique, XII, No. 38, Bruxelles, 1936.

Leloup, E. Contributions à l'étude de la Faune belge. VII. La propagation du crabe chinois en Belgique pendant l'année 1936. Bull. Mus. Roy. d'Hist. Nat. de Belgique, XIII, No. 8, Bruxelles, 1937.

Monro, C. C. A. On a New Species of Serpulid Polychaete from the Shoreham Harbour Canal, Sussex. Ann. and Mag. Nat. Hist., 11th Ser., I, 73—78, London, 1938.

Pax, F. *Anthozoa* (Teil II: *Aciniaria, Octocorallia*). Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), XXX, Teil III.e2, 81—317, Leipzig, 1937.

Prenant, M. Leçons de Zoologie. Prochordés — Tuniciers. Actual. Sci. et Indust., No. 380, Paris, 1936.

Prenant, M. Leçons de Zoologie. Prochordés — Amphioxus. Actual. Sci. et Indust., No. 379, Paris, 1936.

Risbec, J. Recherches anatomiques sur les Prosobranches de Nouvelle-Calédonie. Ann. Sci. Nat. Zool., XX, 189—226, Paris, 1938.

Topsent, E. Sur les *Leucandra* des côtes de France. Bull. Inst. Océanogr., No. 728, Monaco, 1937.

Topsent, E. Sur *Rhizochalina carotta* O. Schmidt et ses affinités. Bull. Mus. Nation. d'Hist. Nat., 2ème Sér., IX, 275—77, Paris, 1937.

Treadwell, A. L. *Hemipodia canadensis* a new Polychaetous Annelid from Nova Scotia. Journ. Biol. Board Canada, III, 348—49, Toronto, 1937.

5) c Distribution and Ecology.

Allee, W. C. and Evans, G. Certain Effects of Numbers Present on the Early Development of the Purple Sea Urchin, *Arbacia punctuta:* A Study in Experimental Ecology. Ecol., XVIII, 337—45, New York, 1937.

Carl, G. C. Flora and Fauna of Brackish Water. Ecol., XVIII, 446—53, New York, 1937.

Clark, A. H. Biological and Oceanographic Conditions in Hudson Bay. XI. Echinoderms of Hudson Bay. Journ. Biol. Board Canada, III, 350—57, Toronto, 1937.

Elton, C. Marine Animals collected by Mr. A. W. Moore at Etah, North-West Greenland, during the Oxford University Ellesmere Land Expedition, 1934—35. Ann. and Mag. Nat. Hist., 10th Ser., XX, 432—34, London, 1937.

Forrest, J. E. and Crichton, M. I. Notes concerning some Animals obtained from three German Warships recently salved at Scapa Flow, Orkney. Scottish Naturalist, No. 229, 3—8, Edinburgh, 1938.

Fraser, J. H. The Distribution of Chaetognatha in Scottish Waters during 1936, with Notes on the Scottish Indicator Species. Journ. du Conseil, XII, 311—20, Copenhague, 1937.

Furnestin, J. Compte rendu de Dragages Géologiques de la 4ème Croisière (8 mai —11 juillet 1935). Rev. Trav. Office Pêches Marit., X, 233—58, Paris, 1937.

Gravier, C. Stomatopodes des Côtes d'Indo-Chine. Ann. Inst. Oceanogr. de Monaco, N. S., XVII, 175—211, Paris, 1937.

Jensen, A. S. Den Kinesiske Uldhaandskrabbe (*Eriocheir sinensis* M. Edw.) i Danmark. Det Kgl. Danske Vidensk. Selsk., Biol. Meddel., XIII, No. 3, København, 1937.

Joubin, L. Cours d'Oceanographie biologique. Bull. Soc. d'Oceanogr. de France, XVII, 1670—79, Paris, 1937.

Kamps, L. F. De Chineesche wolhandkrab in Nederland. Leens, 1937.

Monro, C. C. A. Polychaeta. John Murray Exped. 1933—34, Brit. Mus. (Nat. Hist.), Sci.. Rep., IV, 243—321, London, 1937.

Moore, H. B. Marine Fauna of the Isle of Man. Proc. and Trans. Liverpool Biol. Soc., L, Liverpool, 1937.

Neviani, A. I Briozoi della Laguna veneta. Boll. Pesca, Piscicolt. e Idrobiol., XIII, 383—404, Roma, 1937.

Otter, G. W. Rock-Destroying Organisms in Relation to Coral Reefs. Great Barrier Reef Exped. 1928—29, Brit. Mus. (Nat. Hist.), Sci. Rep., I, 324—52, London, 1937.

Pohl, L. Le Crabe Chinois. Bull. Soc. d'Océanogr. de France, XVII, 1670—79, Paris, 1937.

Raitt, D. S. The Benthic Amphipoda of the North-Western North Sea and Adjacent Waters. Proc. Roy. Soc. Edinburgh, LVII, 241—54, Edinburgh, 1937.

Raitt, D. S. On the Occurrence of *Gammarus* in Scottish Coastal, Brackish and Inland Waters. Scottish Naturalist, No. 228, 155—62, Edinburgh, 1937.

Renouf, L. P. W. Faunistic Notes from the South Coast of County Cork, I. F. S. Ann. and Mag. Nat. Hist., 10th Ser., XX, 477—80, London, 1937.

Stauffer, R. C. Changes in the Invertebrate Community of a Lagoon after Disappearance of Eel Grass. Ecol., XVIII, 427—31, New York, 1937.

Volz, P. Der jährliche Temperaturgang im Meere und sein Einfluss auf die geographische Verbreitung und die Tiefenverbreitung mariner Bodentiere. Forsch. und Fortschr., XIII, 300—01, Berlin, 1937.

Wilson, D. P. The Influence of the Substratum on the Metamorphosis of *Notomastus* Larvae. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 227—44, Cambridge, 1937.

5) d Physiology and Behaviour.

Arey, L. B. The Physiology of the Repugnatorial Glands of Onchidium. Journ. Exper. Zool., LXXVII, 251—86, Philadelphia, 1937.

Azéma, M. Recherches sur le Sang et l'Excrétion chez les Ascidies. Ann. Inst. Océanogr. Monaco, XVII, 1—150, Paris, 1937.

Cole, K. S. Electric Impedance of Marine Egg Membranes. Nature, CXLI, 79, London, 1938.

Dennell, R. On the Feeding Mechanism of *Apseudes talpa*, and the Evolution of the Peracaridan Feeding Mechanisms. Trans. Roy. Soc. Edinburgh, LIX, Pt. I, 57—78, Edinburgh, 1937.

Donahue, J. K. and Jennings, E. D. The Occurrence of Estrogenic Substances in the Ovaries of Echinoderms. Endocrinol., XXI, 690—91, Glendale, Cal., 1937.

Durivault, A. Forme et Mode de Répartition des Spicules chez *Alcyonium palmatum* Pall. Bull. Inst. Océanogr., 2ème Sér., IX, 278—82, Paris, 1937.

Fenizia, G. Sull'istinto di mascheramento dell'*Ethusa mascarone* Herbst. Bull. Inst. Océanogr., No. 732, Monaco, 1937.

Fox, H. M. Functions of the Tube in Sabellid Worms. Nature, CXLI, 163, London, 1938.

Fox, H. M. and Wingfield, C. A. The Activity and Metabolism of Poikilothermal Animals in Different Latitudes. II. Proc. Zool. Soc. London, CVII, Ser. A., 275—82, London, 1937.

Fretter, V. The Structure and Function of the Alimentary Canal of some Species of Polyplacophora (Mollusca). Trans. Roy. Soc. Edinburgh, LIX, Pt. I, 119—64, Edinburgh, 1937.

van Harreveld, A. and Wiersma, C. A. G. The Triple Innervation of Crayfish Muscle and its Function in Contraction and Inhibition. Journ. Exper. Biol., XIV, 448—72, London, 1937.

Kleinholz, L. H. and Welsh, J. H. Colour Changes in *Hippolyte varians*. Nature, CXL, 851—52, London, 1937.

MacGinitie, G. E. The Use of Mucus by Marine Plankton Feeders. Science, LXXXVI, 398—99, U.S.A., 1937.

Maloeuf, N. S. R. The Biology of Light Production among the Arthropods. Science Progress, XXXII, 228—45, London, 1937.

McCance, R. A. and Masters, M. The Chemical Composition and the Acid Base Balance of *Archidoris britannica*. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 273—80, Cambridge, 1937.

McCance, R. A. and Shackleton, L. R. B. The Metallic Constituents of Marine Gastropods. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 269—72, Cambridge, 1937.

Millott, N. On the Structure and Function of the Wandering Cells in the Wall of the Alimentary Canal of Nudibranchiate Mollusca. Journ. Exper. Biol., XIV, 405—12, London, 1937.

Sandon, H. Differential Growth in the Crab *Ocypoda*. Proc. Zool. Soc. London, CVII, Ser. A, 397—414, London, 1937.

Smith, J. E. The Structure and Function of the Tube Feet in Certain Echinoderms. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 345—58, Cambridge, 1937.

Wiersma, C. A. G. and van Harreveld, A. A Comparative Study of the Double Motor Innervation in Marine Crustaceans. Journ. Exper. Biol., XV, 18—31, London, 1938.

5) e Parasitic Forms.

Rothschild, M. Preliminary Note on the Life-History of *Cryptocotyle jejuna* Nicoll, 1907 (Trematoda). Ann. and Mag. Nat. Hist., 11th Ser., I, 238—39, London, 1938.

van Oorde-de Lint, G. M. and Stekhoven, J. H. S. Copepoda. (X.c2: *Copepoda parasitica*). Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), XXXI, 73—198, Leipzig, 1936.

Stekhoven, J. H. S. *Nematoda errantia*. Tierwelt d. Nord- und Ostsee (Grimpe u. Wagler), XXVIII, Teil V.b, 1—173, Leipzig, 1935.

Stekhoven, J. H. S. *Nematoda parasitica*. Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), XXVIII, Teil V.c, 1—47, Leipzig, 1935.

5) f Marine Plants.

Carl, G. C. Flora and Fauna of Brackish Water. Ecol., XVIII, 446—53, New York, 1937.

Fischer-Piette, E. Remarques sur le bois intercotidal d'Aurigny et des Casquets. Bull. Inst. Océanogr., No. 729, Monaco, 1937.

Renn, C. E. The Eel-Grass Situation along the Middle Atlantic Coast. Ecol., XVIII, 323, New York, 1937.

Stauffer, R. C. Changes in the Invertebrate Community of a Lagoon after Disappearance of Eel Grass. Ecol., XVIII, 427—31, New York, 1937.

Young, E. L. Recent Investigation on the Eel-Grass Problem: Preliminary Report. Bull. Mt. Desert Is. Biol. Lab. 1938, 26—28, Salsbury Cove, Me., 1938.

6) Fish.

6) a Systematics, Morphology and Development.

Anon. Important Food Fishes from the Trawling Grounds off the Coast of the Maritime Province (Siberia). Fish. Exper. Stat., Fusan, Chosen, Japan, 1936. (In Japanese, with Latin names of fish).

Anon. Marine Fishes of the Pacific Coast of Mexico. Odawara, Japan, 1937.

Beebe, W. Preliminary List of Bermuda Deep-Sea Fish. Zoologica, XXII, 197—208, New York, 1937.

Chabanaud, P. Qu'est-ce que le "Pleuronecte commersionen" de Lacépède? Bull. Inst. Océanogr., 2ème Sér., IX, 193—98, Paris, 1937.

Deraniyagala, P. E. P. The Sword Fish *Xiphias* of the Indian Ocean. Spolia Zeylanica, Ceylon Journ. of Sci., Sect. B, XX, 347—50, Ceylon, 1937.

Ford, E. Vertebral Variation in Teleostean Fishes. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 1—60, Plymouth, 1937.

Foster, K. W. The Blue Phase in the Color Changes of Fish with Special Reference to the Role of the Guanin Deposits in the Skin of *Fundulus heteroclitus*. Journ. Exper. Zool., LXXVII, 169—213, Philadelphia, 1937.

de Gaetani, D. Uova, sviluppo embrionale e stadi post-embrionali negli *Sparidi*. 5. *Box boops* L. R. Com. Talassogr. Ital., Mem. CCXLI, Venezia, 1937.

Goodrich, E. S. On the Spinal Nerves of the Myxinoidea. Quart. Journ. Microscop. Sci., N.S., LXXX, 153—58, London, 1937.

Gudger, E. W. The Natural History and Geographical Distribution of the Pointed-Tailed Ocean Sunfish (*Masturus lanceolatus*), with Notes on the Shape of the Tail. Proc. Zool. Soc. London, CVII, Ser. A, 353—96, London, 1937.

Haines, R. W. The Posterior End of Meckel's Cartilage and Related Ossifications in Bony Fishes. Quart Journ. Microscop. Sci., N.S., LXXX, 1—29, London, 1937.

Hart, J. L. Sexual Dimorphism in vertebral Number in the Capelin, *Mallotus villosus* (Müller). Journ. Biol. Board Canada, III, 417—20, Toronto, 1937.

Hollister, G. Caudal Skeleton of Bermuda Shallow Water Fishes. II. Order Percomorphi, Suborder Percesoces: *Atherinidae, Mugilidae, Sphyraenidae*. Zoologica, XXII, 265—79, New York, 1937.

Moore, H. B. Marine Fauna of the Isle of Man. Proc. and Trans. Liverpool Biol. Soc., L, Liverpool, 1937.

Norman, J. R. Diagnoses of new Nototheniiform Fishes collected by the "Discovery" Expedition. Ann. and Mag. Nat. Hist., 10th Ser., XX, 475—76, London, 1937.

Roule, L. Considérations sur plusieurs poissons abyssaux de structure aberrante. Bull. Inst. Océanogr., No. 726, Monaco, 1937.

Schultz, L. P. Redescription of the Capelin *Mallotus catervarius* (Pennant) of the North Pacific. Proc. U.S. Nation. Mus., LXXXV, 13—20, Washington, 1937.

6) b Physiology and Behaviour.

Ara, L. Contributo allo studio dell'alimentazione dei pesci: *Sargus vulgaris* Geoffer, — *Sargus annularis* L., — *Sargus sargus* L. Boll. Pesca, Piscicolt. e Idrobiol., XIII, 371—81, Roma, 1937.

Barry, D. R. Changes of Colour by Injection of Pituitary Extracts in a Dogfish (*Scylliorhinus canicula*). Nature, CXL, 769—70, London, 1937.

Breder, C. M. The Perennial Flying Fish Controversy. Science, N.S., LXXXVI, 420—22, U.S.A., 1937.

von Buddenbrock, W. Beobachtungen über das Sterben gefangener Seefische und über den Milchsäuregehalt des Fischblutes. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CI, 4ème Part., 2, Copenhague, 1938.

Dorsey, H. G. More about "Flying Fish". Science, N.S., LXXXVI, 612—13, U.S.A., 1937.

Fessard, A. and Sand, A. Stretch Receptors in the Muscles of Fishes. Journ. Exper. Biol., XIV, 383—404, London, 1937.

Fleischmann, W. und Kann, S. Wirkung von Hypophysenhormonen auf den Farbwechsel einiger Adriafische. Zeitschr. vergleich. Physiol., XXV, 251—55, Berlin, 1937.

Franz, G. Über den Reflex des Gasspuckens bei Fischen und die Funktion des weberschen Apparates. Zeitschr. vergleich. Physiol., XXV, 193—238, Berlin, 1937.

von Frisch, K. The Sense of Hearing in Fish. Nature, CXLI, 8—11, London, 1938.

Halsey, J. T. and Minnich, B. A Study of the Action of Certain Drugs on the Vessels of the Dogfish. Bull. Mt. Desert Is. Biol. Lab. 1938, 16—18, Salsbury Cove, Me., 1938.

Hardenberg, J. D. F. Preliminary Report on a Migration of Fish in the Java Sea. Treubia Deel 16, Afl. 2, 295—300, Buitenzorg, 1937.

Harris, J. E. The Role of the Fins in the Equilibrium of the Swimming Fish: II. The Role of the Pelvic Fins. Journ. Exper. Biol., XV, 32—47, London, 1938.

Khalil, F. Die Bedeutung der Schwimmblase für die Atmung der Fische. Zeitschr. vergleich. Physiol., XXV, 256—82, Berlin, 1937.

von Ledebur, J. Beiträge zur Physiologie der Schwimmblase der Fische. V. Über die Beeinflussung des Sauerstoffbindungvermögens des Fischblutes durch Kohlensäure bei hohem Sauerstoffdruck. Zeitschr. vergleich. Physiol., XXV, 156—69, Berlin, 1937.

von Ledebur, J. und Wunder, W. Beiträge zur Physiologie der Schwimmblase der Fische. IV. Beobachtungen an Stichlingen, die ihre Schwimmblase nicht mit Gas füllen konnten. Zeitschr. vergleich. Physiol., XXV, 149—55, Berlin, 1937.

Loewenstein, O. The Tonic Function of the Horizontal Semicircular Canals in Fishes. Journ. Exper. Biol., XIV, 473—82, London, 1937.

Loosanoff, V. L. The Spawning Run of the Pacific Surf Smelt, *Hypomesus pretiosus* (Girard). Internat. Rev. d. ges. Hydrobiol., XXXVI, 170—83, Leipzig, 1937.

Marshall, E. K. and Litchfield, J. T. Absorption and Excretion of Sulfanilamide in Fish. Bull. Mt. Desert Is. Biol. Lab. 1938, 15, Salsbury Cove, Me., 1938.

Myers, G. B. "Flying" Fish. Science, N.S., LXXXVI, 442, U.S.A., 1937.

Picotti, M. Limiti di resistenza termoalina per alcune specie ittiche vallive. Boll. Pesca, Piscicolt. e Idrobiol., XIII, 144—64, Roma, 1937.

Pugsley, L. I. The Distribution of Vitamins A and D in some Organs of British Columbia Herring, Pilchard, Grayfisk and Halibut. Progress Rep. Pacific Biol. Stat., Nanaimo, B.C. and Pacific Fish. Exper. Stat., Prince Rupert, B.C., No. 33, 8—10, Canada, 1937.

Smith, W. W. The Excretion of Inorganic Phosphate in *Squalus acanthias*. Bull. Mt. Desert Is. Biol. Lab. 1938, 29, Salsbury Cove, Me., 1938.

Souillé, M. Recherches sur la teneur en glutathion de la branchie des poissons. Bull. Inst. Océanogr., No. 731, Monaco, 1937.

Storey, M. The Relation between Normal Range and Mortality of Fishes due to Cold at Sanibel Island, Florida. Ecol., XVII, 10—26, New York, 1937.

6) c Parasites and Diseases.

Bedford, R. H. Bacteria in the Gut of Line Caught Halibut. Progress Rep. Pacific Biol. Stat., Nanaimo, B.C. and Pacific Fish. Exper. Stat., Prince Rupert, B.C., No. 33, 23—24, Canada, 1937.

Ladreyt, F. Sur l'évolution et l'étiologie de certaines ophtalmies chez les poissons vivant en aquarium. Bull. Inst. Océanogr., No. 730, Monaco, 1937.

Raabe, H. Études de Microorganismes parasites des poissons de mer. II. *Thallamoebella parasitica* n.g., n.sp. Bull. Inst. Océanogr., No. 737, Monaco, 1937.

Trawinski, A. Recherches sur l'infection des poissons par les trichines. Bull. Inst. Océanogr., No. 736, Monaco, 1937.

7) Marine Fishes.

7) a Commercial Fisheries: Statistical.

Ahlf, R. Die deutsche Hochseefischerei. Jahresber. Deutsch. Fisch. 1936, 273—87, Berlin, 1937.

Bower, W. T. Alaska Fishery and Fur-Seal Industries in 1936. U.S. Bureau Fish. Admin. Rep. No. 28, Washington, 1937.

Buddenböhmer, Dr. Die Hauptvereinigung der Deutschen Fischwirtschaft. Jahresber. Deutsch. Fisch. 1936, 243—51, Berlin, 1937.

Eichelbaum, E. Die Seefischerei. Jahresber. Deutsch. Fisch. 1936, 5—70, Berlin, 1937.

England. Report on Sea Fisheries for the Year 1936. Min. Agric. and Fish., London, 1937.

Fischer, E. Die Küstenfischerei und Kutter-Hochseefischerei. Jahresber. Deutsch. Fisch. 1936, 293—315, Berlin, 1937.

Fischer, E. Die wichtigste Fischereiliteratur aus dem Jahre 1936. A. Seefischerei. Jahresber. Deutsch. Fisch. 1936, 391—96, Berlin, 1937.

Flagisse, M. La Nécessité d'une Refonte totale de la Réglementation de la Pêche Maritime. La Pêche Marit. etc., XXI, 1—2, Paris, 1938.

Gruvel, A. et Besnard, W. Atlas de Poche des principaux Produits marins rencontrés sur les Marchés de Maroc. Paris, 1937.

Ireland. Report on the Sea and Inland Fisheries for the Year 1936. Dept. Agric. (Fish. Branch), Dublin, 1937.

Martinez, J. G. Les Actividades Perqueras de Mexico en 1936. Bol. Depart. Forest. y de Caza y Pesca, III, No. 8, 140—50, Mexico, 1937.

Netchajeff, A. Le Chalutage du Bateau de la Station Ichtyologique "Ustrem". Trav. Stat. Ichtyol. Sozopol — Bulgarie, T. V. 3—19, 1937. (In Bulgarian, French Résumé).

Roddewig, K. Der örtliche und zeitliche Verlauf der Hochseefischerei ausserhalb der Küstengewässer. Jahresber. Deutsch. Fisch. 1936, 71—166, Berlin, 1937.

Thompson, D'A. W. Bulletin Statistique des Pêches Maritimes des Pays du Nord et de l'Ouest de l'Europe. XXV pour l'Année 1935. Cons Perm. Internat. pour l'Explor. de la Mer. Copenhague, 1937.

7) b Fish Technology.

Anon. Ein neues biologisches Frischhaltungsverfahren für Fische. Fischmarkt, N.F., VI, 23—25, Cuxhaven, 1938.

Beatty, S. A. The Measurement of the Spoilage of Fresh Fish. Progress Rep. Atlant. Biol. Stat., St. Andrews, N.B. and Atlant. Fish. Exper. Stat., Halifax, N.S., No. 20, 3—5, Canada, 1937.

Brocklesby, H. N. and Green, K. Methods for the Production of Oils from Fish Livers of Low Oil Content. II. A Note on a Modified Digestion Process. Progress Rep. Pacific Biol. Stat., Nanaimo, B.C., and Pacific Fish, Exper. Stat., Prince Rupert, B.C., No. 33, 7, Canada, 1937.

Cooper, D. le B. Fish Drying. Progress Rep. Atlant. Biol. Stat., St. Andrews, N.B., and Atlant. Fish. Exper. Stat., Halifax, N.S., No. 20, 8—10, Canada, 1937.

Cooper, D. le B. A New Way to tell when to Flake and when to Pile Salt Fish. Progress Rep. Atlant. Biol. Stat., St. Andrews, N.B., and Atlantic Fish. Exper. Stat., Halifax, N.S., No. 20, 10, Canada, 1937.

Huréquin, L. Vernis anti-acide pour la protection du fer-blanc des boîtes de conserves. La Pêche Marit., etc., XX, 335—36, Paris, 1937.

Kahl, W. Betrachtungen über das Heringsfass. Fischmarkt, N.F., V, 288—92, Cuxhaven, 1937.

Labrie, A. and Gibbons, N. E. Studies on Salt Fish. II. The Effect of Salt Concentration on Preservation. Journ. Biol. Board. Canada, III, 439—49, Toronto, 1937.

Macpherson, N. L. Newfoundland Cod Liver Oil. Newfoundland Dept. Nat. Resources, Fish. Res., Bull. No. 3, St. John's, 1937.

Pugsley, L. I. The Vitamin A Content of Grayfish Liver Oil *(Squalus sucklii)*. Progress Rep. Pacific Biol. Stat., Nanaimo, B.C., and Pacific Fish. Exper. Stat., Prince Rupert, B.C., No. 34, 3—7, Canada, 1937.

Senner, P. L'Anguille d'Europe. Pêche et Utilisation industrielle. La Pêche Marit., etc., XX, 403—05, Paris, 1937.

Thompson, H. Science and the Fisheries. Essential for Establishment of Trade Enterprise. Fishing News, 19, Aberdeen, 1—I—38.

7) c Fishing Vessels and Gear.

Anon. Aberdeen Trawl Net Invention. Experiments prove its success. Fishing News, 10, Aberdeen, 6—XI—37.

Anon. Preservation of Fish Nets and Lines. How best results are secured. Fishing News, 13, Aberdeen, 27—XI—37.

Herrington, W. C. The Use of Large-Meshed Otter Trawls in the New England Fishery. Cons. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CI, 4ème Part., 1, App. F, Copenhague, 1937.

Phillips, J. B. Notes on Sardine Gear Changes at Monterey. California Fish and Game, XXIII, 221—23, San Francisco, 1937.

Stern, F. Die Entwicklung des Loggerbaues der Emder Heringsfischereien. Ver. Fluss- u. Küstenschiffswerften Deutschlands, H. 6, 1937.

Sunderland, P. A. Gear and Bait for Grayfish and Sharks. Progress Rep. Pacific Biol. Stat., Nanaimo, B.C., and Pacific Fish. Exper. Stat., Prince Rupert, B.C., No. 34, 16—17, Canada, 1937.

Takenouti, Y. The Nature of the Fishing Net and its Application to the Broad Break of the Net. III. Bull. Japan. Soc. Scient. Fish., VI, 167—70, Tokyo, 1937.

7) d Fishing Grounds.

Anon. Exploraciones de carácter científico y técnico-comerciales en aguas mexicanes. Bol. Depart. Forest. y de Caza y Pesca, III, Num. 8, 153—73, Mexico, 1937.

Schnakenbeck, W. Zur Lage der Fischerei an der Unterelbe. Deutsch. Fischwirtsch., IV, 620—22, Berlin, 1937.

8) Marine Fishery Investigations.

8) a Stocks and Effects of Fishing.

Thompson, H. Science and Fishery Research. Development of Organised Investigations. Fishing News, 12, Aberdeen, 18—XII—37.

Thompson, W. F. Theory of the Effect of Fishing on the Stock of Halibut. Rep. Internat. Fish. Comm., No. 12, Seattle, 1937.

8) b Cod.

Fridriksson, A. Fiskirannsóknir, VI. Ársrit Fiskifélags Islands 1937, Reykjavik, 1937.

Johnston, W. W. Some Characteristics of the Enzymes of the Pyloric Caeca of Cod and Haddock. Journ. Biol. Board Canada, III, 473—85, Toronto, 1937.

Thompson, H. Relative Strength of Year-Classes of Certain Fishes of the Western Atlantic. A. Cod. Cons. Perm. Internat. p. l'Explor de la Mer, Rapp. et Proc.-Verb., CI, 4ème Part., 1, 17, Copenhague, 1938.

8) c Haddock.

Herrington, W. C. Relative Strength of Year-Classes of Certain Fishes of the Western Atlantic. C. Haddock. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CI, 4ème Part., 1, 17, Copenhague.

Johnston, W. W. Some Characteristics of the Enzymes of the Pyloric Caeca of Cod and Haddock. Journ. Biol. Board Canada, III, 473—85, Toronto, 1937.

8) f Plaice.

Carruthers, J. N. A Note on Plaice Fluctuations in the Southern North Sea. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 14—15, Copenhague, 1937.

Jensen, A. J. C. The Reduction of the Stock of Plaice in the Southern Horns Reef Area through intensive Trawling in Later Years. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 40—41, Copenhague, 1937.

Tcherneff, S. Données comparatives concernant la Plie dans les Etangs et dans la Mer Noire. Trav. Stat. Ichtyol.. Sozopol — Bulgarie, T. V, 52—67, 1937. (In Bulgarian, French Résumé).

8) h Halibut.

Brocklesby, H. N. and Riddell, W. A. Chemical and Biochemical Studies of Halibut. II. Iced Fish. Progress Rep. Pacific Biol. Stat., Nanaimo, B.C., and Pacific Fish. Exper. Stat., Prince Rupert, B.C., 17—19, Canada, 1937.

Riddell, W. A., Brocklesby, H. N. and Pugsley, L. I. Chemical and Biochemical Studies of Halibut. I. Iced and Frozen Muscle Juice. Progress Rep. Pacific Biol. Stat., Nanaimo, B.C., and Pacific Fish. Exper. Stat., Prince Rupert, B.C., 13—16, Canada, 1937.

Thompson, W. F. Theory of the Effect of Fishery with Stock of Halibut. Rep. Internat. Fish. Comm., No. 12, Seattle, 1937.

Whitmore, A. J. The Canadian Halibut Fleet. Prov. Brit. Columbia, Rep. Prov. Fish. Dept. for the Year ended December 31st, 1936, 45—48, Victoria, B.C., 1937.

8) j Herring.

Anon. Quelques Prévisions pour la prochaine campagne de pêche du hareng en Manche orientale et dans le sud de la Mer du Nord. La Pêche Marit., etc., XX, 329—30, Paris, 1937.

Carruthers, J. N. and Hodgson, W. C. Similar Fluctuations in the Herrings of the East Anglian Autumn Fishery and Certain Physical Conditions. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 10—13, Copenhague, 1937.

Erdmann, W. Untersuchungen über die Zusammensetzung der Heringsschwärme in der nördlichen Nordsee 1936. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 42—50, Copenhague, 1937.

Fischer, E. Die Grosse Heringsfischerei. Jahresber. Deutsch. Fisch. 1936, 288—92, Berlin, 1937.

Fridriksson, A. Fiskirannsóknir, VI. Ársrit Fiskifélags Islands 1937, Reykjavik, 1937.

Gilson, G. Fluctuation and Oscillation in a Community of Pure Spent Herrings. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 63—67, Copenhague, 1937.

Hansen, P. Fiskeriundersøgelserne ved Vestgrønland i 1936. Beretn. og Kundg. vedr. Grønlands Styrelse, Nr. 2, København, 1937.

Hart J. L. and Tester, A. L. Tagging of Herring in British Columbia: Methods, Apparatus, Insertions, and Recoveries during 1936—37. Prov. Brit. Columbia, Rep. Prov. Fish. Dept. for the Year ended December 31st, 1936, 55—67, Victoria, B.C., 1937.

Hessle, C. Investigations of the Herring in the Archipelago off Stockholm. Svenska Hydrogr.-Biol. Komm. Skr., N.S., Biol., II, Nr. 2. Stockholm, 1937. (In Swedish, English Résumé).

Järvi, T. H. Hajanaisia havaintoja. 24. Laatokan suurmuikku: "rääpys". Suomen Kalastuslehti, XLIV, 196—99, Helsinki, 1937.

Lovern, J. A. and Wood, H. Variations in the Chemical Composition of Herring. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 281—94, Cambridge, 1937.

Marshall, S. M., Nicholls, A. G. and Orr, A. P. On the Growth and Feeding of the Larval and Post-Larval Stages of the Clyde Herring. Journ. Mar. Biol. Assoc. U.K., N.S., XXII, 245—68, Cambridge, 1937.

Savage, R. E. The Food of North Sea Herring 1930—1934. Min. Agric. and Fish., Fish. Invest., Ser. II, Vol. XV, No. 5, London, 1937.

Schnakenbeck, W. Die deutschen Arbeiten über den Hering in der nördlichen Nordsee während der Jahre 1931—35. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 5—6, Copenhague, 1937.

Schroeder, W. C. Relative Strength of Year-Classes of Certain Fishes of the Western Atlantic. D. Herring. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CI, 4ème Part., 1, 17, Copenhague, 1938.

Smith, W. C. A Report on some Results of a Scientific Investigation of the Composition of the Manx Herring Shoals. Fish. Board, Isle of Man, Douglas, 1937.

Tesch, J. J. Racial Investigations on Herring Larvae in the South-Western Inlets of Holland. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 7—9, Copenhague, 1937.

Tesch, J. J. Observations on Length, Age Distribution and Growth of Herring in the Flemish Bight and off Dieppe 1936—37. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 68—71, Copenhague, 1937.

Wiliamson, H. C. Sea Fish — and Reproduction. Spawning of Herring. I and II. Fishing News, 15, and 7, Aberdeen, 1—I—38, and 8—I—38.

8) k Sardine and Other Clupeoids.

Dakin, W. J. The Occurrence of the Australian Pilchard, *Sardinops neopilchardus* (Steind.), and its Spawning Season in New South Wales Waters, together with brief Notes on other New South Wales Clupeids. Proc. Linn. Soc. N.S. Wales, LXII, 209—16, Sydney, 1937.

Demel, K. Quelques Remarques sur la Pêche des Sprats au Cours de la Saison 1936/37. Biul. Stacji Morsk. w Helu, Nr. 2, 1937. (In Polish, French Résumé).

Hart, J. L. Tagging British Columbia Pilchards: Methods and Preliminary Results. Prov. Brit. Columbia, Rep. Prov. Fish. Dept. for the Year ended December 31st, 1936, 49—54, Victoria, B.C., 1937.

Janssen, J. F. First Report of Sardine Tagging in California. California Fish and Game, XXIII, 190—204, San Francisco, 1937.

Phillips, J. B. Sizes of California Sardines Caught in the Different Areas of the Monterey and San Pedro Regions. Div. Fish and Game Calif., Fish. Bull. No. 50, Sacramento, 1937.

8) l Tunny and Mackerel.

Fick, H. Der Fang von Thunfischen und Heringshaien. Fischmarkt, N.F., V, 292—94, Cuxhaven, 1937.

Huréquin, L. À la recherche du vrai thon. La Pêche Marit., etc., XX, 407—08, Paris, 1937.

Lissner, H. Zur Biologie der Makrele des Bosporus. Internat. Rev. d. ges. Hydrobiol., XXXVI, 184—212, Leipzig, 1937.

Sette, O. E. Relative Strength of Year-Classes of certain Fishes of the Western Atlantic. E. Mackerel. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CI, 4ème Part., 1, 17, Copenhague, 1938.

Thiel, H. Thunfisch und Thunfischfang. Fischmarkt, N.F., VI, 4—9, Cuxhaven, 1938.

8) m Other Commercial Species.

Demel, K. Note sur la Reproduction de l'Orphie (*Belone acus* Risso) à la Côte Polonaise. Biul Stacji Morsk. w Helu, Nr. 2, 1937. (In Polish, French Résumé).

8) o Whales and Seals.

Bower, W. T. Alaska Fishery and Fur-Seal Industries in 1936. U.S. Bureau Fish., Admin. Rep. No. 28, Washington, 1937.

Hentschel, E. Naturgeschichte der nordatlantischen Wale und Robben. Handb. Seefisch. Nordeuropas (Lübbert und Ehrenbaum), III, H. 1, Stuttgart, 1937.

Matthews, L. H. The Humpback Whale *Megaptera nodosa*. Discovery Rep., XVII, 7—92, Cambridge, 1937.

Osborne, W. A. Why do stranded Whales die? Nature, CXL, 1017, London, 1937.

Peters, N. Deutschland wieder auf Walfang. Natur und Volk, LXVII, 546—54, Frankfurt a. M., 1937.

9) Freshwater Fisheries and Fishery Investigations.

9) a Salmonidae.

Alm, G. Laxynglets Tillväxt i Tråg och Dammar. Kungl. Lantbruksstyrelsen, Nr. 14, Stockholm, 1937.

Bailey, B. E. The Pigments of Salmon. Journ. Biol. Board Canada, III, 469—72, Toronto, 1937.

Blair, A. A. The Validity of Age Determination from the Scales of Landlocked Salmon. Science, N.S., LXXXVI, 519—20, U.S.A., 1937.

Clemens, W. A. Contributions to the Life-History of the Sockeye Salmon. Prov. Brit. Columbia, Rep. Prov. Fish. Dept. for the Year ended December 31st, 1936, 26—44, Victoria, B.C., 1937.

England. Salmon and Freshwater Fisheries Report for the Year 1936. Min. Agric. and Fish., London, 1937.

Foerster, R. E. The Relation of Temperature to the Seaward Migration of Young Sockeye Salmon (*Oncorhynchus nerka*). Journ. Biol. Board Canada, III, 421—38, Toronto, 1937.

Fry, F. E. J. and Kennedy, W. A. Publications of the Ontario Fisheries Research Laboratory. LIV. Report on the 1936 Lake Trout Investigation, Lake Opeongo, Ontario. Univ. Toronto, Biol. Ser., No. 42, Toronto, 1937.

Hile, R. Morphometry of the Cisco, *Leucichthys artedi* (Le Sueur), in the Lakes of the Northeastern Highlands, Wisconsin. Internat. Rev. d. ges. Hydrobiol. usw., XXXVI, 57—130, Leipzig, 1937.

Hobbs, D. F. Natural Reproduction of Quinnat Salmon, Brown and Rainbow Trout in Certain New Zealand Waters. New Zealand — Mar. Dept., Fish. Bull., No. 6, Wellington, 1937.

Hoover, E. Experimental Modification of the Sexual Cycle in Trout by Control of Light. Science, N.S., LXXXVI, 425—46, U.S.A., 1937.

Huntsman, A. G. Relative Strength of Year-Classes of certain Fishes of the Western Atlantic. B. North American Atlantic Salmon. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CI, 4ème Part., 1, 9—15, Copenhague, 1938.

Menzies, W. J. M. The Movements of Salmon marked in the Sea. II. The West Coast of Sutherland in 1937. Fisheries, Scotland, Salmon Fish., 1938, No. I, Edinburgh, 1938.

Morris, R. T. "Flying" Salmon. Science, N.S., LXXXVI, 442, U.S.A., 1937.

Motherwell, J. A. Report on the Salmon-Spawning Grounds of British Columbia, 1936. Prov. Brit. Columbia, Rep. Prov. Fish. Dept. for the Year ended December 31st, 1936, 68—74, Victoria, B.C., 1937.

Nall, G. H. Sea-Trout of the River Conon. Fisheries, Scotland, Salmon Fish., 1937, No. IV, Edinburgh, 1937.

Pritchard, A. L. The Findings of the British Columbia Pink Salmon Investigation. Part I. Introduction and General Observations. Progress Rep. Pacific Biol. Stat., Nanaimo, B.C., and Pacific Fish. Exper. Stat., Prince Rupert, B.C., No. 33, 3—6, Canada, 1937.

Pritchard, A. L. The Findings of the British Columbia Pink Salmon Investigation. Part II. Marking Experiments and Natural Propagation. Progress Rep. Pacific Biol. Stat., Nanaimo, B.C., and Pacific Fish. Exper. Stat., Prince Rupert, B.C., No. 34, 8—12, Canada, 1937.

Pritchard, A. L. Variation in the Time of Run, Sex Proportions, Size, and Egg Content of Adult Pink Salmon (*Oncorhynchus gorbuscha*) at McClinton Creek, Masset Inlet, B.C. Journ. Biol. Board Canada, III, 403—16, Toronto, 1937.

Ricker, W. E. The Food and the Food Supply of Sockeye Salmon (*Oncorhynchus nerka* Walbaum) in Cultus Lake, British Columbia. Journ. Biol. Board Canada, III, 450—68, Toronto, 1937.

Sato, R. On New Migratory Courses of Salmon (*Oncorhynchus*) cleared by the Tagging Experiments in the Fishing Ground of Northern North Pacific 1936. I. Red. Salmon (*Oncorhynchus nerka* (Walb.)). Bull. Japan. Soc. Sci. Fish., VI, 171—74, Tokyo, 1937. (In Japanese, English Résumé).

Shapovalov, L. Trout and Salmon Marking in California. California Fish and Game, XXIII, 205—07, San Francisco, 1937.

Shapovalov, L. Experiments in Hatching Steelhead Eggs in Gravel. California Fish and Game, XXIII, 208—14, San Francisco. 1937.

Siedlecki, M. The Protection of Sturgeon, Salmon and Sea Trout in the Vistula. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., 3ème Part., 72—74, Copenhague, 1937.

Spencer, J. Fishways. California Fish and Game, XXIII, 215—20, San Francisco, 1937.

Zandt, F. Zur Biologie des Blaufelchen (*Coregonus wartmanni* Bl.) des Bodensees. Internat. Rev. d. ges. Hydrobiol. usw., XXXVI, 138—69, Leipzig, 1937.

9) b Eels.

Athanassopoulos, G. Biologie de l'Anguille. Civelles inanitiées. Internat. Rev. d. ges. Hydrobiol. usw., XXXVI, 213—15, Leipzig, 1937.

Athanassopoulos, G. Sur la Biologie de l'Anguille. Espèces de Montées des Civelles. Internat. Rev. d. ges. Hydrobiol. usw., XXXVI, 216—17, Leipzig, 1937.

Athanassopoulos, G. Sur une Épizootie des Civelles et Anguilles. Internat. Rev. d. ges. Hydrobiol. usw., XXXVI, 218—22, Leipzig, 1937.

Athanassopoulos, G. Sur la Biologie de l'Anguille. Encore sur la Montée des Civelles en 1936. Internat. Rev. d. ges. Hydrobiol. usw., XXXVI, 223—24, Leipzig, 1937.

Athanassopoulos, G. Petites Anguilles inanitiées. Internat. Rev. d. ges. Hydrobiol. usw., XXXVI, 225, Leipzig, 1937.

Hornyold, A. G. Observations sur le nombre de zones des écailles de 12 grandes Anguilles de l'Étang de Berre. Bull. Inst. Océanogr., No. 725, Monaco, 1937.

Hornyold, A. G. Les écailles et les otolithes d'une Anguille de 106 cm. de l'Étang de Berre. Bull. Inst. Océanogr., No. 734, Monaco, 1937.

Hornyold, A. G. L'Âge et la Croissance de 215 petites Anguilles jaunes de l'Étang de Salces (Aude et Pyrénées-Orientales). Bull. Soc. Cent. d'Aquic. et de Pêche, XLIV, 69—74, Paris, 1937.

Hornyold, A. G. Observations sur des petites Anguilles jaunes de Cap d'Ail (Alpes-Maritimes). Bull. Soc. Cent. d'Aquic. et de Pêche, XLIV, 75—78, Paris, 1937.

Jensen, A. S. Remarks on the Greenland Eel, its Occurrence and Reference to *Anguilla rostrata*. Medd. Grønland udg. Komm. vid. Unders. Grønland, CXVIII, Nr. 9, København, 1937.

Roule, L. La migration génétique des Anguilles d'Europe (*Anguilla anguilla* L.). Bull. Inst. Océanogr., No. 733, Monaco, 1937.

Senner, P. L'Anguille d'Europe. Pêche et Utilisation industrielle. La Pêche Marit., etc., XX, 403—05, Paris, 1937.

9) c Other Commercial Species.

Siedlecki, M. The Protection of Sturgeon, Salmon and Sea Trout in the Vistula. Cons. Perm. Internat. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., CV, 3ème Part., 72—74, Copenhague, 1937.

9) d Effects of Pollution.

Bergström, H. och Vallin, S. Vattenförorening genom avloppsvattnet från sulfatcellulosafabriker. Kungl. Lantbruksstyrelsen, Nr. 13, Stockholm, 1937.

10) Shellfisheries.

10) a Molluscs.

Anon. Oyster Merchants discuss their Problems. Fishing News, 9, Aberdeen, 27—XI—37.

Bonnot, P. Setting and Survival of Spat of the Olympia Oyster, *Ostrea lurida*, on Upper and Lower Horizontal Surfaces. California Fish and Game, XXIII, 224—28, San Francisco, 1937.

Cole, H. A. New Pallial Sense Organs in Early Fixed Stages of *Ostrea edulis*. Nature, CXLI, 161, London, 1938.

England. Oyster Cultivation. Min. Agric. and Fish., Fish. Notice, No. 19, London, 1937.

Hopkins, A. E. Experimental Observations on Spawning, Larval Development, and Setting in the Olympia Oyster *Ostrea lurida*. Bull. Bureau Fish., No. 23, Washington, 1937.

Loosanoff, V. L. Spawning of *Venus mercenaria* (L.). Ecol., XVIII, 506—15, New York, 1937.

Schaefer, M. B. Attachment of the Larvae of *Ostrea gigas*, the Japanese Oyster, to Plane Surfaces. Ecol., XVIII, 523—27, New York, 1937.

10) b Crustacea.

Hess, E. A Shell Disease in Lobsters (*Homarus americanus*) caused by Chitinovorous Bacteria. Journ. Biol. Board Canada, III, 358—62, Toronto, 1937.

Templeman, W. Egg-Laying and Hatching Postures of the American Lobster (*Homarus americanus*). Journ Biol. Board Canada, III, 339—42, Toronto, 1937.

Templeman, W. Habits and Distribution of Larval Lobsters (*Homarus americanus*). Journ. Biol. Board Canada, III, 343—47, Toronto, 1937.

11) Miscellaneous.

11) a General.

Fauré-Fremiet, E. et Cougny, A. Propriétés de l'Ichtyocolle provenant de diverses sortes de vessies natatoires. Bull. Inst. Océanogr., 2ème Sér., IX, 188—92, Paris, 1937.

Ford, E. Fishery Investigations. Science Progress, XXXII, 331—34, London, 1937.

Henning, W. *Thalassobionie* und *thalassophile Diptera Nematocera.* Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), XXVII, Teil XI.e3, 85—102, Leipzig, 1935.

Lindberg, H. *Halophile* und *halobionte Hemiptera.* Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), XXX, Teil XI.e4, 103—24, Leipzig, 1936.

Maloeuf, N. S. R. The Biology of Light-Production among the Arthropods. Science Progress, XXXII, 228—45, London, 1937.

White, H. C. Local Feeding of Kingfishers and Mergansers. Journ. Biol. Board Canada, III, 323—38, Toronto, 1937.

11) b Mathematical and Statistical Methods.

Buchanan-Wollaston, H. J. Two Technical Notes. Journ. du Conseil, XII, 333—34, Copenhague, 1937.

Ringleb, F. Mathematische Methoden der Biologie, insbesondere der Vererbungslehre und der Rassenforschung. Leipzig und Berlin, 1937.

Recent Publications of the International Council:

RAPPORTS ET PROCÈS-VERBAUX.

Vol. 102: *Foreign Guests in the Baltic and Transition Areas. Scientific Report of the Baltic and Transition Area Committees.* Mai 1937. Kr. 6.00.

Vol. 103: *Critical Review of the Methods used for determining Nutrient Salts and Related Constituents in Sea Water.* Mai 1937. Kr. 2.00.

Vol. 104: *Rapport Atlantique 1934/1935.* Juin 1937. Kr. 2.00.

Vol. 105: *Part I: Procès-Verbaux (Juillet — 1937).* Octobre 1937. Kr. 3.00.
Part II: Rapport Administratif (1936—1937). Octobre 1937. Kr. 3.00.
Part III: Appendices. Octobre 1937. Kr. 3.00.

Vol. 106: *Fluctuations in the Baltic Stock of Salmon.* In press.

BULLETIN HYDROGRAPHIQUE *pour l'année 1936.* Janvier 1938. Kr. 7.00.

BULLETIN STATISTIQUE *pour l'année 1935.* Septembre 1937. Kr. 3.00.

Attention is drawn to Series E:—

FAUNE ICHTHYOLOGIQUE DE L'ATLANTIQUE NORD, of which Nos 1—17 have been issued. No. 18 with a List of Contents, now in preparation, will complete this Series. Each, Kr. 4.00.

Table of Contents.

		Page
1.	Obituary:— **Charles Green** (1876—1938) by **S. Kemp**	3
2.	Editorial Notice: Appearance of the *Journal of Marine Research*	6
3.	**Joh. van Veen.** Water Movements in the Straits of Dover	7
4.	**W. R. G. Atkins, G. L. Clarke, H. Pettersson, H. H. Poole, C. L. Utterback** and **A. Ångström.** Measurement of Submarine Daylight	37
5.	**John P. Tully** and **Neal M. Carter.** A Simplified Procedure for Colorimetric Analyses of Sea Water	58
6.	**John P. Tully.** The Expression of Sea-Water Analyses as Milligram-Atoms per Litre	67
7.	**Albert L. Tester.** Variation in the Mean Vertebral Count of Herring *(Clupea pallasii)* with Water Temperature	71
8.	**Michael Graham.** Rates of Fishing and Natural Mortality from the Data of Marking Experiments	76
9.	**G. P. Farran.** On the Size and Number of the Ova of Irish Herrings	91
10.	Reviews	101
11.	Current Bibliography prepared by the Editor with the assistance of Miss **Thursby-Pelham**	132

A/S L. IHRICH – COPENHAGEN